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State of Montana

Proposal

for

LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

VOLUME TWO: GEOTECHNICAL APPENDIX

March 1, 1991

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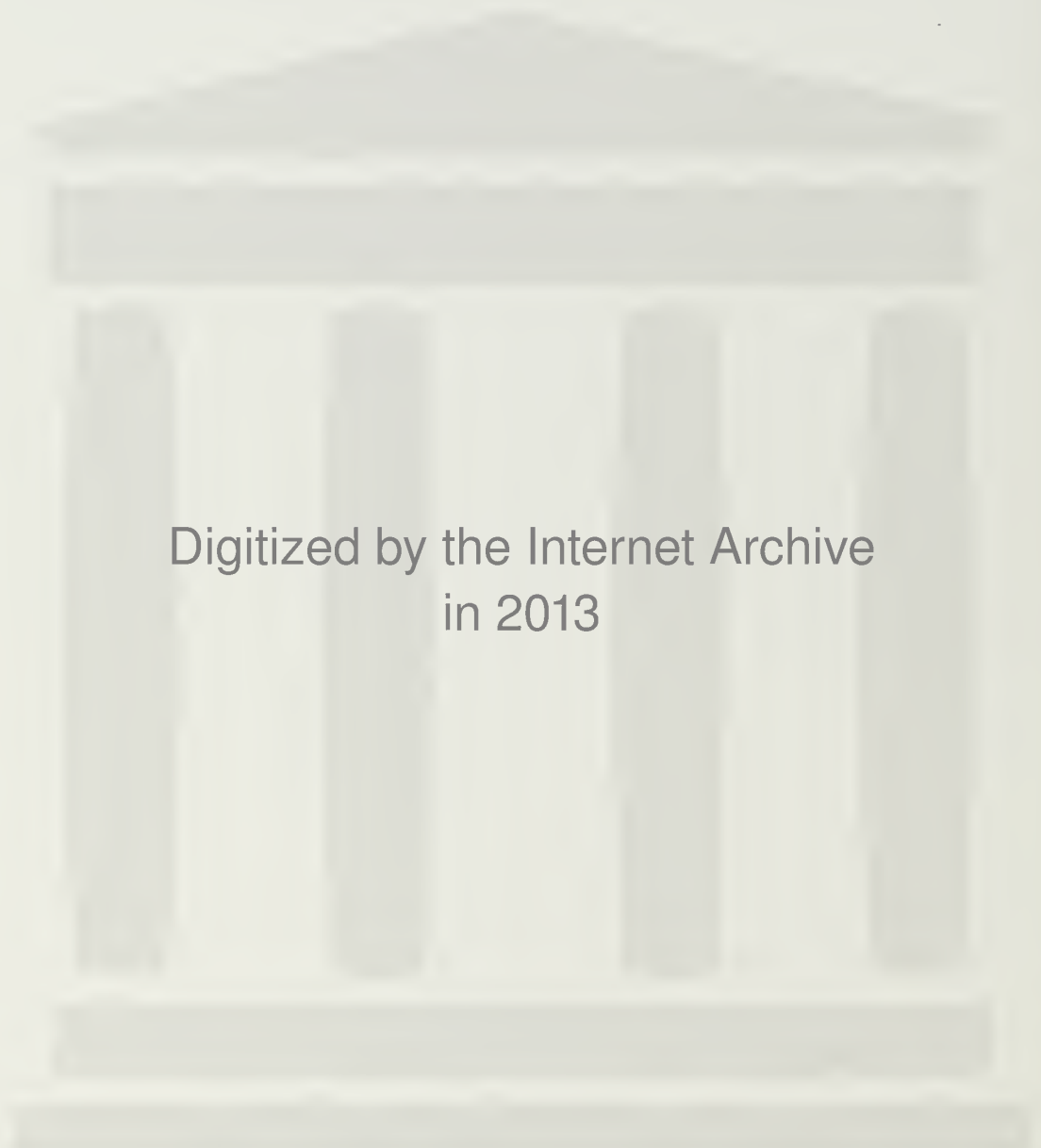
PREFACE

The information contained in this Geotechnical Appendix is reprinted from the State of Montana Proposal for the U.S. Department of Energy Superconducting Supercollider (SSC), submitted in September, 1987.

Although certain elements of the SSC do not apply to the LIGO Project (such as underground tunneling, collider ring, etc.) the earlier proposal contained a great deal of information valuable to the instant project. The State of Montana contracted with a private firm to conduct the geotechnical research element of the state's SSC proposal; this investment was valued at approximately $500,000. Conditions at the proposed site have not changed appreciably since 1987; we believe the information contained in this Appendix represents a significant saving of time, cost, and effort in successfully locating one of the observatory sites.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The Comanche Basin site has many physical characteristics and supporting regional resources that make it an attractive location for the super collider.

Comanche Basin is located in south central Montana on a plain overlooking the Yellowstone River Valley, about twenty miles northwest of the city of Billings. Figure 1 locates the site with respect to Billings, the State of Montana and adjacent states and highlights the six units of the Montana State University System.

Site topography is generally flat with some rolling terrain. Current land use is almost exclusively dryland farming and grazing. Population is sparse in the immediate area. An aerial photograph, Figure 3, taken in June 1987 captures the agricultural character of the site.

The proposed location of the super collider facility is partly outlined on Figure 4, an aerial photograph taken slightly north of the site and looking southeast from an elevation of about 8500 feet above ground level. The farming community of Broadview, population about 120, is visible in the near center of the photograph. The campus area is near the left border. Some low points in the basin contain shallow ponds during wet seasons, as evident from the photograph. Due to low annual precipitation and high evaporation rates, such ponds tend to be transient.

Favorable topography and geology permit nearly ideal setting of the collider ring with flexibility for location refinements. The terrain allows efficient layout of the facility. Flat, or slightly dipping, stable sedimentary bedrock with thin overburden will permit rapid excavation and tunneling and will significantly reduce construction costs and risks.

GEOLOGY AND TUNNELING

As a result of natural processes acting over geologic time, Comanche Basin is an ideal site for the super collider. This unique area has special geologic characteristics that make it ideally suited for the facility.

SUITABILITY FOR EFFICIENT CONSTRUCTION OF UNDERGROUND STRUCTURES

Flat site topography, varying only a few hundred feet over an area of some 300 square miles, favors efficient project layout and construction of underground structures. The proportions of the site area, roughly 16 miles wide and 20 miles long, are ideal to accommodate the super collider facility and allow flexibility for location adjustment during final design.

An exploratory drilling program in mid 1987 confirmed that the site's structural geology is simple and straightforward. Bedrock consists of flat-lying or gently dipping Cretaceous and early Tertiary sedimentary formations, predominantly sandstone and shale, characterized as "softrock." There is only a thin alluvial cover in the ring area. Underground structures can be safely and economically excavated in these rock units. Tunneling by tunnel boring machine will advance rapidly. Where tunnel depths are less than 50 feet, approximately 6 percent of the collider ring, cut-and-cover excavation will further reduce construction costs.

Tunnel and structural excavation will generate significant quantities of spoil material, at least two-thirds of which will have properties similar to clayey or silty sand. With the exception of small amounts of high-plasticity clay soils, this material is suitable for structural fill and site grading, thus avoiding off-site disposal costs. Any excess can be used for access roads within an average surface-haul distance of two miles.

The site's geohydrology is well-suited to underground construction and presents minimum water problems. This is due to low rainfall, high evaporation and surface topography that naturally removes water from the collider ring area. Around the ring, the internally drained alluvial cover is thin. The underlying sedimentary formations contain some wells of sufficient capacity for cattle and domestic use. Although moderate groundwater flows will be encountered at some locations during tunnel excavation, extensive dewatering is not expected, based on the relatively low capacity of existing wells.

STABILITY AND SEISMICITY

Although sedimentary formations at the site are relatively soft, they generally exhibit excellent stability, bearing capacity and durability. Rock units in the experimental areas can readily support the required heavy foundation loads without shear failure or significant settlement. No conditions are expected that would result in settlement or ground movement that would adversely affect facility operations.

The site is located in an area characterized by low seismicity within recent geologic time and is defined as Uniform Building Code Risk Zone 1, the lowest category of seismic activity. Since 1869, when the records began, only five recorded earthquake events had epicenters within 100 miles of the site. These events ranged in magnitude from 2.8 to 4.0

Known fault zones occur along the southwest margin of the site area, the largest of which is about 5 miles long. Literature on regional faulting suggests that the latest movement along these zones may have been post Eocene or Pliocene in age. It appears that the most recent mappable movement of the fault zone is on the order of 1.6 million years ago.

INSTALLATION AND OPERATIONAL EFFICIENCY

The collider ring has been placed in a folded plane to make best use of site topography. The east and west interaction points are on horizontal planes at different levels. The west side of the ring is 280 feet higher to accommodate terrain differences and minimize depth to experimental halls and the tunnel. The tunnel arcs are in a plane sloping slightly downward to the east. The average depth from the surface to tunnel center line is about 120 feet, affording installation and operational efficiency.

The tunnel location can be further optimized in both horizontal and vertical dimensions when more detailed topographic and geological data are obtained after Best Qualified List selection.

ABSENCE OF MAJOR CONSTRUCTION RISKS

Flat topography, simple geologic structures, low seismicity and favorable groundwater conditions all combine to substantially reduce the risk of unexpected problems during excavation and tunneling. The 1987 geotechnical exploration program provided information on underground conditions at strategic locations around the facility as well as providing specific properties for each rock unit that will be encountered. Accordingly, major construction risks should be low.

REGIONAL RESOURCES

This region has excellent resources to support construction and operation of the SSC project. As the major trade and service center for the region, Billings offers all supporting services and facilities needed for project construction and for SSC staff, family and visitors.

TRANSPORTATION

Billings has excellent airport, highway and railroad systems. Billings Logan International Airport, largest commercial airport in a five-state area, is twenty-five minutes from the site and four minutes from downtown Billings. Serviced by four international airlines and a regional commuter line, the airport offers connections to cities throughout the U.S. and Canada.

Montana State Highway 3, an established truck route, bisects the site and connects it to the city of Billings. Billings is the meeting point for all primary road systems including I-94 and I-90.

Billings is also an important hub in the extensive Burlington Northern (BN) Railroad network, a Class One rail system that serves 25 states and two Canadian provinces. A newly upgraded BN rail line runs through the SSC site, parallel to State Highway 3.

The airport, highways and railroad, in relation to Billings and the site, are shown on Figure 6.

INDUSTRIAL AND CONSTRUCTION RESOURCES

A skilled, experienced labor force of approximately 64,500 and a diversified economy provide Billings with one of the best industrial and construction resource bases in the Northwest. Large-scale mining and construction projects, including construction of four coal-fired generating plants, 200 USAF Minuteman missile sites and major oil and coal exploration operations, are contributing factors to the immediate accessibility of well-developed construction resources and a highly mobile work force. Most of the nation's largest equipment manufacturers and vendors have distribution services and regional warehouses in Billings. High technology firms with experience relating to SSC construction needs are based in the area.

Montana ranks fourth nationally in worker productivity. Montana has competitive base wage rates for construction trades. Montana's overall wage scale is about 12 percent less than the national average.

HOUSING

Billings and the surrounding area have an ample supply of quality rentals and affordable homes within commuting distance of the site. In June 1987, there were 2000 single-family homes and 100 condominiums and townhomes for sale. Approximately 900 multi-family and apartment rental units are available. The average purchase cost of a three-bedroom home in the area is $69,000. Multi-family housing rent ranges from $250 to $400 per month. Single-family housing rent ranges from $300 to $750.

MEDICAL AND EMERGENCY SERVICES

Billings is a medical center, providing advanced health care services to a four-state area. Two modern, fully equipped hospitals (totaling 540 beds), 16 clinics and hundreds of physicians offer every major medical specialty and a complete range of services and emergency care. A helicopter emergency lifesaving program, fully equipped and staffed by a medical flight team, and fixed-wing air and ground ambulances provide advanced life support systems.

Yellowstone County has a comprehensive law enforcement system. The Billings police department has jurisdiction in the city. The Yellowstone County sheriff's department provides service to the remainder of the county.

Fire emergencies in the Billings area are handled by a full-service fire department commended as one of the best units in the Northwest by the Western Fire Chiefs Organization. County and volunteer organizations manage fire-related emergencies for outlying communities.

RECREATION

The site is only a few hours from Yellowstone National Park, national forests and wilderness areas, and within minutes of a multitude of recreational facilities.

Montanans have the luxury of being able to vacation in the same state where they live and work — even in the winter.

Three of the five entrances to Yellowstone Park are in Montana. The most spectacular, the Beartooth Highway, is close to Billings. It offers breathtaking mountain scenery at every turn.

"The most beautiful road in America is U.S. 212 which leaves Red Lodge, climbs to the Beartooth Pass at 11,000 feet and drops down into the northeast entrance of Yellowstone Park...Hearst would have built his castle on the Red Lodge-to-Cooke City highway if he'd have known about it." *Dateline America, 1979, CBS, Inc., Charles Kurault.*

Billings takes advantage of the outdoor action. You can tell a lot by what's on top of cars — rafts, skis, camping gear, bikes, canoes, trophy elk. Or, what they're trailing — snowmobiles, horses, sailboats, speed boats. Golf clubs are in the trunk.

EDUCATIONAL AND CULTURAL RESOURCES

Montana public schools are among the best in the nation in terms of student achievement and quality of education. Overall, the state's education system ranks third in the nation and has received high marks nationally in scholastic achievement. The six-unit Montana University System and community education programs have produced an educated, skilled population. Research is an integral part of the university system. The Montana Science and Technology Alliance, a joint economic partnership between the state and the private sector, is designed to strengthen Montana's business climate through investments in research and development.

The Montana Legislature has authorized the Science and Technology Alliance to create "Centers of Excellence" linked to the University system. The Alliance and the University System have, in turn, designated the Comanche Basin site as a candidate location for such a center if the SSC is located there.

The state fosters a rich cultural environment with a wealth of events ranging from performances by internationally acclaimed classical musicians to traditional pow-wows by one of the Indian tribes in the state. Music, theater, art, dance, opera and ballet are established cultural offerings in the Billings area.

Based on the Preliminary Environmental Evaluation, the impacts from siting, constructing, operating and decommissioning the SSC would be relatively insignificant due to the nature of the existing site environment and land use. The site vicinity does not support any known federally listed threatened or endangered species. Because the site ecosystem is not unique, it will be possible to comply with appropriate environmental requirements within reasonable limits of time and cost. In cases where mitigation of adverse environmental impacts is necessary, such mitigation can be accomplished.

WETLANDS

The U.S. Geological Survey 1:24,000-scale topographic maps show no marshes within the site. Other small surface water bodies in the internally drained basin do exhibit some features characteristic of wetlands (see Figure 5.2-1). These water features may constitute wetlands as defined by DOE in its regulations implementing Executive Order 11990—Protection of Wetlands (10 CFR 1022 et seq). Confirmation of the type and location of wetlands will be completed as a part of the wetlands assessment portion of the project's EIS process.

SURFACE WATER

The SSC facility would be located largely within the drainage of the Comanche Basin, with portions of the SSC ring intersecting ephemeral streams on the fringes of the Lake Basin and Painted Robe Creek watersheds to the west. Maps indicate 399 miles of intermittent streams and 25 miles of perennial small streams in the Comanche Basin. The low ratio of total stream distance to surface area of the basin, 1.84 miles/per square mile, indicates the relative aridity of the basin. The intermittent streams carry water when runoff is heavy, usually during spring. Approximately one year in ten, heavy runoff causes minor flooding of some streams.

Surface water samples were taken in the summer of 1987 from four small ponds and a stream in the site area. Tests on these samples indicate high pH and high total dissolved solids (up to 8000 mg/L) in the surface waters of Comanche Basin. These results are consistent with soil conditions, drainage patterns and climate of the area.

FISH AND WILDLIFE

Overall, the Comanche Basin area is not considered to be a unique or uncommon wildlife habitat; similar habitat exists in abundance in the region. The surface water resources and vegetation in the vicinity of the site provide habitat for a moderate range of wildlife species. Agricultural activities have altered the natural habitat and influenced the kinds and numbers of wildlife species.

Pronghorn antelope and mule deer are the predominant big-game species. There are no antelope wintering areas in the vicinity. Mule deer tend to inhabit the wooded areas and broken side slopes of drainages to the east of the site. This area, outside the site perimeter, has been identified in a 1974 study as critical mule deer habitat. More recent studies have not identified any mule deer winter ranges or year-long high density areas near the proposed site.

The most prevalent predators in the region include the coyote, bobcat, lynx and red fox. Their incidence at the proposed site is unknown. Numerous small mammals include the jackrabbit, cottontail rabbit, prairie dog, ground squirrel, and many small rodents, such as the western deer mouse.

Sage grouse are the most widely distributed and abundant game-bird species. They are primarily associated with the sagebrush communities in the grassland basin and in the pine forested area east of the site. Sharp-tailed grouse can be expected to concentrate near the ridges bordering the Comanche Basin to the east. Introduced game-bird species may occur in the area.

In wet years, Comanche Basin surface water features may attract waterfowl populations close to 100,000 for breeding and stopovers. In dry years, waterfowl breeding is limited and populations total in the hundreds. The largest breeding area within the proposed site is the Spidel Waterfowl Production Area, three miles northeast of Broadview, administered by the U.S. Fish and Wildlife Service.

Other wildlife in the general area includes raptors, such as golden eagles and red-tailed hawks, and numerous species of passerine birds. Various reptiles and amphibians inhabit the site area.

One study of the area concluded that "the temporary ponds and marshes in the area...do not support a fishery of any importance." Any fish are likely to have been stocked. The Montana Department of Fish, Wildlife and Parks indicates that their only fishery in the area is Broadview Pond, which they plan to manage as a bass-crappie fishery.

VEGETATION

Comanche Basin is characterized primarily by mid-grass prairie, with some wetland vegetation in lowland areas and ponderosa pine cover on the rock outcroppings and broken drainage slopes outside the site's eastern perimeter.

AIR QUALITY

Sources of air pollutants in the site area include agricultural activities which generate particulates. Petroleum refineries and a coal-fired power plant in Billings emit sulfur dioxide, nitrogen dioxide and particulates. The Billings sources are downwind twenty miles to the southeast of the site. Dispersion modeling conducted by the State of Montana Air Quality Bureau for the Billings area indicates that no significant concentrations of any regulated pollutant should occur at that distance from Billings.

BACKGROUND RADIATION

The sedimentary rocks underlying the Comanche Basin contain very small amounts of radioactive elements that contribute to the low background radiation observed. There are two geologic formations under the Comanche Basin that may contain slightly elevated concentrations of uranium and other radioactive elements. These formations are the Bearpaw Shale, which locally contains deposits of bentonite, and the Virgelle Sandstone, a favorable environment for "Texas" roll-type deposits that may contain uranium concentrations.

HISTORICAL AND ARCHAEOLOGICAL RESOURCES

The Montana State Historic Preservation Office (SHPO) has identified 85 prehistoric and historic sites, mostly tipi rings and lithic scatters, within the general region of the proposed SSC site. Only one of the recorded sites, a log hotel which once was the Antelope Stage stop on the historic stage route from Billings to Lavina, is listed on the National Register of Historic Places. It can be incorporated within the campus expansion area.

The area has not been extensively or systematically surveyed to date and other sites may exist. SHPO believes that the recorded sites are probably representative of the range of site types that occur there. Most of the cultural resources at the recorded sites are relatively common to the general region.

TITLE DELIVERY

The State of Montana has prepared a real estate acquisition plan that will deliver defendable title to the Government within the required schedule. Over 250 landowners in the general site area have been identified and their property boundaries located. However, land must be acquired from only 72 landowners, including the State of Montana and the Federal Government. Most of the resident landowners have indicated a willingness to discuss purchase of their land for use by the project.

For lands currently owned by the State, land will be exchanged with the Bureau of Land Management for subsequent transfer to administrative control of the DOE. For land privately held, a public or quasi-public corporation will be established with power to acquire land for the super collider and transfer it to the Government. A special session of the Legislature will be held, early in 1988, to facilitate land acquisition and transfer.

FLEXIBILITY

Favorable site topography, geology and land use allow flexibility to adjust the location of SSC facilities on the site.

NATURAL AND MANMADE FEATURES

There are no natural features in the region of the site that will adversely affect siting, construction or operation of the facility. To the contrary, the natural characteristics of the site favor efficient site development.

Principal manmade features in the site area are electrical transmission lines, the Broadview substation, the BN rail line, Highway 3 and a system of county roads, generally at one-mile spacing on section lines. These features are all assets in site development and access.

The city of Broadview, located inside the north arc, and scattered ranches throughout Comanche Basin will not appreciably affect project operation. Billings, twenty miles to the south, will not cause interference.

NOISE AND VIBRATION

The only potential sources for noise and vibration in the area are Montana State Highway 3, the Burlington Northern Railroad and agricultural equipment. The highway and rail line would be at least five miles from the SSC interaction points and should not adversely impact operation.

CLIMATE

There are no known climatic conditions that could adversely impact construction and operation of the SSC at Comanche Basin. The area's climate is mild compared to cities of similar latitude to the east (e.g. Chicago, Minneapolis). The Billings area frequently has mild, "open" winters when arctic cold bypasses the area completely.

Snow accumulations over six inches are uncommon. Local roads and airport facilities rarely close. For example, Montana State Highway 3, the major access route to the site from Billings, has been closed due to snow only two hours in the last twenty years.

Summers are warm, sunny and dry. Skies are blue. Average annual precipitation is about 15 inches. Humidity is low—the July daytime average is 35 percent. The sun shines 219 days a year.

RELIABLE AND STABLE POWER SUPPLY

The site area is served by Montana Power Company (MPC), a utility with an excellent balance of hydroelectric and coal-fired generation and firm power purchase agreements. In 1986, MPC's peak generation was 1,233 MW, 73 percent of its capacity. In addition, MPC is interconnected by two 500 kV transmission lines and a number of 230 kV lines to large electrical supply systems in the Northwest.

The Broadview substation, inside the collider ring and six miles from the campus area, interconnects seven major transmission lines 230 kV or higher, any one having the capacity to provide full-load service to the SSC. The two 500 kV lines connect the 2,060 MW Colstrip generating station and the Bonneville Power Administration's Garrison switchyard 225 miles to the west. The 230 kV lines connect Great Falls and Billings. Because of these interconnections to large power generation facilities and transmission line redundancy, the collider site could not be placed in a more stable and reliable location for power supply.

MPC expects load growth of about 1.8 percent over the next nine years without consideration of the SSC. MPC plans to build a 240 MW combined-cycle unit at its Mill Creek substation to respond efficiently to future load demands, including the SSC. Based on the addition of this unit, the estimated cost of energy delivered to the site is 34 mills/kWhr in 1987 dollars.

RELIABLE WATER SUPPLY

Water for the SSC will be delivered to the southeast perimeter of the collider, about ten miles from the campus, through a new 16-18 inch pipeline from the Billings city water service. The pipeline and pumping station, with a capacity of 2600 gpm, will be constructed through a Rural Special Improvement District.

Billings has a reliable and abundant water supply from the Yellowstone River. The city has in place more than adequate treatment and supply capacity to satisfy the SSC industrial cooling and potable water needs. Further treatment at the site should be minimal and relatively inexpensive, since the water already meets drinking water standards.

AVAILABLE FUEL AND WASTE DISPOSAL FACILITIES

Fuel for the SSC will be provided from a new natural gas pipeline from the Montana Power Company system. A new 4 inch branch line off the existing 6 inch Big Coulee line will be run through the town of Broadview to the east cluster. A 2 inch branch line will be run from the 4 inch line south to a pressure-reducing/metering station at the west cluster. The company has long-term reserves and supplies under contract adequate for SSC requirements well into the future.

Adequate sewage treatment facilities do not exist within a practical distance of the site. A treatment plant will need to be constructed by DOE. Several locations exist near the campus for siting an evaporation pond for treatment of effluent combined with cooling tower blowdown.

Billings operates a solid waste landfill south of the city with capacity estimated to be adequate for both city and SSC needs through the year 2010. Contractor-operated waste disposal trucks are available for hauling material to the landfill. Low-level hazardous waste can be trucked to a licensed site in Colorado or Utah. A firm specializing in transport of this material is headquartered in Billings.

VOLUME 3

GEOLOGY AND TUNNELING

3.1 GENERAL

3.1.1 Proposed Location

The proposed location, as shown on Figure 3.1-1, is in the south-central portion of Montana within 20 highway miles of the city of Billings. The tunnel ring is predominantly in the northwest corner of Yellowstone County, which contains about 20 miles (40 percent) of the ring length and 75 percent of the offered land. The remainder of the ring and land areas extend into the three adjoining counties of Stillwater to the west, Golden Valley, and Musselshell to the north.

The site is in the Comanche Basin. The perimeter of the basin is 300 to 400 feet higher than the low points in the center. Elevations around the ring will generally vary from 3850 feet on the east to 4150 feet on the west. The tunnel elevation is primarily controlled by the elevations of the Burlington Northern Railroad and State Highway 3, which passes over the northern and southern arc regions of the tunnel. The site is generally flat with some gently rolling terrain, and appears to be an ideal location for the facility.

Some low points contain transient ponds during wet seasons; however, the climate tends to be arid in this region, and water will not be a problem because the basin-like topography channels runoff towards the basin center and away from the collider ring. The land is used for dryland farming or grazing, and because of low rainfall, large crops are generated only about once every three years. There is very little overburden, and rock outcrops are visible around the site. The entire tunnel will be founded in bedrock.

The proposed detailed location is shown on Figure 3.1-3, in the map folder. These are maps prepared from 7.5-minute USGS quadrangle maps (Scale 1 inch = 2,000 feet). There are six maps comprising two quadrangles each which cover the site.

The proposed center of the collider ring is located at Longitude 108°51'14" and Latitude 46°00'54", which is in the NE 1/4 of the NW 1/4 of Sec. 15, T3N, R23E, Broadview, East Quadrangle, MPM.

The long axis lies in a general north-south direction with a bearing calculated from the quadrangle map of 26 degrees, 31 minutes and 8 seconds west of true north.

The Burlington Northern Railroad and State Highway 3 run parallel through the site and cross the ring at its southeast and northeast quadrants. Broadview, the only town within the ring, is adjacent to the railroad within 3 miles of the northern-most ring perimeter. High voltage power transmission lines cross the ring in an east-west and north-west direction.

The profile of the ring has been established so that the two long sides containing the experimental halls and campus area are level. The west side is 280 feet higher than the east side to accommodate terrain differences and provide for shallower excavations for the west structures. The north and south tunnel arcs follow the same sloping plane, which is skewed in plan 10.8 degrees to the longitudinal collider axis. The vertical slope and vertical curves of the arcs meet SSC design criteria. The profile is shown on Figure 3.1-4, in the map folder.

The campus cluster is located on the east side of the ring closest to State Highway 3 to provide for shorter access to Billings and the airport. The terrain in the campus area is flatter than on the west side and is more suitable for these facilities.

The site is crossed by many county roads with gravel surfaces. This road network is ideal for access to the many points around the ring where facilities are located. Improvements to the roads are expected during the construction phase.

A number of alternative collider locations were examined. The proposed location appears to be nearly optimum. Perhaps some further refinement could be made; however, it was concluded that within the time constraints any change would be limited to movement of the ring center less than a half mile. It was further concluded that the USGS maps are not accurate enough to justify further optimization of the ring location.

3.2 GEOLOGY

In this section, the regional geology of east central Montana is discussed as well as the geology of the Comanche Basin. The geologic conditions specific to the proposed ring location and structures are also presented.

Within this section, soils are classified in accordance with ASTM D2487 Classification of Soils for Engineering Purposes. Rock units are described in accordance with AGI terminology, except that the alternative silty or argillaceous sandstone is used rather than wacke, since the former is more universally understood in this area than the latter.

The regional geology has been characterized based on published maps and literature, and on the experience of Northern Engineering and Testing, Inc., which has done extensive work in the region. At the site, data was taken from ten new borings drilled into distinct formations around the ring as well as site observations, material testing and data taken from older borings when Montana Power Company transmission structures were routed. Logs from wells were reviewed. The site was visited, and materials tested and evaluated by Alfred J. Hendron Jr., Ph.D., and personnel from Northern Engineering and Testing, Inc., and Stone & Webster Engineering Corp. The data and evaluations presented in this volume are based on substantial factual information and considerable experience and technical expertise.

3.2.1 Regional Geology

The proposed site lies at the western edge of the Great Plains, within a finger of plains about 100 miles wide inserted between the Snowy Mountains to the north, the Pryor Mountains to the south and the Crazy Mountains to the west, as shown on Figure 3.2-1 in the map pocket. The site is located about 50 miles from each of these uplifted areas, at an elevation of about 4000 feet.

Mid-to-late Cretaceous and early Tertiary marine sedimentary units, including silty and/or argillaceous sandstone, siltstone and claystone, are exposed in the area. These units have been moderately folded and locally faulted by the adjacent mountain building during Cretaceous and early Tertiary time (Freeze and Cherry, 1979; Johns, 1982).

As the regional uplift occurred during the Cretaceous/Tertiary period, higher energy sedimentation began to dominate. As a result, most of the rock units in this area are characterized by high sand-silt content rather than the high silt-clay content characteristic of the same units further east.

The Yellowstone River, about 20 miles to the south of the proposed site, cuts through the various upper Cretaceous and lower Tertiary rock units, and at Billings, the river bed is in the Middle Cretaceous Cody shale, with the Eagle formation creating the surrounding cliffs.

More specifically, the Comanche Basin is an unglaciated, closed basin. The basin is surrounded by low rolling hills, the erosional remnants of the east limb of the Big Coulee-Hailstone Dome, a broad northwest-southeast trending anticline, and the uplifted resistant sandstone units along the en echelon shear zone known as the Lake Basin Fault Zone, forming the southwestern boundary of the proposed site (Alpha and Fanshawe, 1954; Freeze and Cherry, 1979; Sonnenberg, 1956).

Hydrocarbon deposits, primarily natural gas, are present near the center of the Big Coulee-Hailstone Dome to the west, but no major petroleum production or other deposits have been discovered through extrapolation within the proposed site area.

There are no major streams in the basin, and alluvial deposits are thin to absent, except in the center of Comanche Flat, where clay, sand and silt have been deposited by seasonal runoff into the basin.

3.2.2 Site Geology

Around the ring, alluvial cover is thin, and colluvium from the underlying bedrock is the principal soil. Bedrock units generally dip from 0 to 20 degrees east, along the exposed east limb of the Big Coulee-Hailstone Anticline, except along the southwest portion of the site, where en echelon faulting along the Lake Basin Fault Zone has tilted, uplifted and/or dropped some of the rock units.

Near-surface and exposed bedrock units are late Cretaceous and early Tertiary sedimentary formations, including Eagle, Claggett, Judith River, Bearpaw and Lennep, all Cretaceous; and the Hell Creek-Tullock formations, which are boundary formations including both Cretaceous and Tertiary, without an obvious contact. These are shown in Figure 3.2-2 and at a 10 to 1 vertically distorted cross-section in Figure 3.2-3. Photographs of each of the exposed geological formations are provided as Figure 3.2-4. Near the center of Comanche Flat there is a significant accumulation of quaternary alluvium. The bedrock formations and alluvium are described below from oldest to youngest (Lawlor, 1956).

- Eagle; Keu: This formation contains three distinct units (a) an upper thin-bedded silty sandstone containing rounded, black chert pebbles within a fine to medium grained sand matrix, (b) a middle thin-bedded argillaceous sandstone with interbedded carbonaceous shale seams, and (c) a lower massive, medium grained silty sandstone. The latter unit forms cliffs (rimrocks) around local basins, notably at Billings, but exposures of this unit are limited in the site area. The sandstone is massive and friable; upper units are more friable and weather readily. The Eagle is a locally limited aquifer. The stratigraphic thickness of the Eagle formation in the site area is 250 to 400 feet.

- Claggett, Kcl: This formation includes dark grey to grey claystone and sandy claystone interbedded with thin argillaceous sandstone seams. It is generally capped with a persistent argillaceous sandstone unit, while the lower units contain calcareous concretions. Below the cap unit, most of the claystone and sandstone beds are soft and weather readily. The stratigraphic thickness in the site area is 200 to 300 feet.

- Judith River, Kjr: This formation consists of interbedded buff, tan and white silty sandstones, and light gray to black sandy claystone interbeds near the center of the formation. Sandstone units are commonly crossbedded and tuffaceous. Claystone units contain shell and plant fragment fossils and lignite lenses. The upper sandstone units are moderately resistant and form ridges and low hills on the west side of the site. The sandstone units are low-volume aquifers in the site area. The stratigraphic thickness of the Judith River formation is 250 to 400 feet.

- Bearpaw, Kb: This formation is primarily grey to black, massive marine claystone, with some thin, calcareous argillaceous sandstone units in the upper 50 feet of formation. Some of the claystone units, in the lower 50 feet of the formation have significant bentonite content, (Berg, 1969; Knechtel and Patterson, 1956) and the claystone in these units is expansive with decomposition and moisture (and/or oxygen) increase. The claystone has high sulfate content. It weathers readily forming low areas with saline seeps. The claystone is impermeable, except along local fractures and gypsum-filled fissures. At this location, the Bearpaw formation contains significantly more sand and silt than farther east or northeast. The Bearpaw formation varies from 150 to 350 feet thick in the site area.

- Lennep, Kl: This formation is well cemented, tuffaceous silty sandstone, including a fairly massive lower unit, a middle andesitic unit and an upper tuffaceous unit. It is moderately friable and weather resistant and forms a ridge east of Broadview. The Lennep is about 60 feet thick in the site area, and is stratigraphically equivalent to the Fox Hills formation elsewhere in Montana.

- Hell Creek/Tullock Formations, Khc/Tt: These formations include tan to yellowish, cross-bedded silty and/or argillaceous sandstone units interbedded with thin bluish-gray sandy claystone units. Sandstones are lenticular and discontinuous, and significant carbonaceous layers are present in both formations. Rock units are friable, weather readily and exposures are mostly concealed with colluvium. In the site area, this formation is approximately 75 percent sandstone and 25 percent sandy claystone and/or siltstone. Although these two formations are the boundary between Cretaceous and Tertiary, the contact is generally gradational and uncertain. Within the site area, these formations are more than 500 feet total thickness.

- Quaternary Alluvium, Qal: Alluvial deposits consist primarily of clay, silt and sand, weathered and decomposed from the nearby soft bedrock units, transported, and deposited along the surface drainages and low areas of the basin. The thickest alluvial deposits are inside of the ring area, where adjacent streams have deposited sediments into the undrained Comanche Flat area to reported depths of up to 75 feet. These soils are soft, and generally saturated.

3.2.3 Tunnel Profile

Nearly all of the tunnel lies within upper Cretaceous and Lower Tertiary sandstone, siltstone, and claystone bedrock units. The geotechnical characteristics of these materials are discussed in detail in other portions of this volume. The following narrative describes, section by section, the material in which the tunnel will be constructed. This information is shown on Figure 3.1-4 in the map folder. The narrative begins at the east campus complex at F10 and proceeds clockwise. Stationing starts with F10 as zero and proceeds clockwise. For station locations, see large scale profile Figure 3.1-4.

- F10 to E1 (0 to 27000) - In this reach, the tunnel will be about 100 to 200 feet below the ground surface in the Hell Creek and Tullock formations.

At this elevation these interbedded sandstone, siltstone and claystone units are very dense and contain occasional carbonaceous layers. Sandstone units contain significant amounts of fine silt and some clay, and are, therefore, relatively impermeable. Only small groundwater seepage is expected, primarily confined to a few of the cleaner sandstone lenses and some of the carbonaceous units. The rock units are sound and relatively unfractured, except for the bedding fracture, which dips about 4 to 6 degrees easterly. Rock units will be about 75 percent sandstone and 25 percent sandy claystone or siltstone.

- F1 area (27,000 to 28,400) – Here the tunnel will encounter the Lennep formation, which is stratigraphically equivalent to the Fox Hills further east. This medium-grained, crossbedded, massive sandstone unit contains significant amounts of silt and clay and is relatively dense. Whereas the sandstone is somewhat friable in outcrops, at tunnel depth it will be very competent.

- F1 – E2 (28,400 to 49,400) – The tunnel, which will be from 50 to 120 feet deep in this reach, will pass through the Bearpaw formation, which is silty and/or sandy claystone in the upper 50 feet of the formation. With depth, the clay content increases and the lower 50 feet of the formation contains thin bentonite beds. The formation is fairly massive claystone, but contains fissures in the more plastic zones. The bedding dips about 5 degrees easterly. The claystone units are relatively impermeable, and the formation in this area is an aquiclude. Moisture content decreases with depth, as does expansion potential. A moisture profile is attached to the log of Boring DH-9 in Appendix 3A. It is apparent at the site that the expansion potential is decreased to a minimum at depths below 25 feet and claystone is at moisture equilibrium, having the properties of soft rock, below 40 feet depth. Most of the tunnel will be constructed in this zone of the formation. The claystone will be relatively easy to excavate at tunnel depth.

- E2 to E3 (49,400 to 70,200) – In this reach the tunnel, which will be about 15 to 120 feet below the surface, will encounter the Judith River formation. While there are some thin claystone interbeds near the center of the formation, it is primarily medium-grained, massive, friable sandstone. Fractures are slight to moderate, except for the bedding fractures, which dip about 5 degrees easterly. These sandstone units yield the principal domestic water in the area, yet flows are small, on the order of 1 to 3 gallons/square foot/day, from the most pervious units. Excavation of the sandstone units is expected to be relatively easy.

- E3 to F3 (70,200 to 93,200) - Within this section of tunnel, at depths of 50 to 150 feet, the Claggett formation will be encountered. The formation consists of interbedded sandstone and sandy claystone units which are moderately fractured, but competent at tunnel depth. Within this reach, the units have been locally folded in a broad anticline, so that bedding dip varies from about 5 degrees easterly to horizontal to 3 degrees westerly. Due to the significant clay content of the units, permeability is low and groundwater flows are expected to be slight. The rock units at tunnel depth will be abut 40 percent sandstone and 60 percent sandy claystone or siltstone.

- F3 to F4 (93,200 to 119,000) - In this section, the tunnel is at depths varying from about 50 to 180 feet below the surface and will encounter the Judith River formation, similar to that described from E2 to E3, except that sandstone will be more fractured, and groundwater flows may increase in and adjacent to the fault zone between E4 and E5.

- F4 to K3 (119,000 to 130,800) - Within this reach, which is bounded by two fault zones, the tunnel alignment varies from 100 feet below the surface to the ground surface and will encounter Bearpaw formation, as described from 28,400 to 49,400 (F1 - E2), in the first half of the section. The second half will encounter some alluvium and colluvium, derived from the underlying Judith River formation, and consisting of Sandy, Lean Clay (CL), and weathered Judith River formation, which will be friable, fractured sandstone. The last half of the section is one of the three small areas within which the tunnel is at or near the ground surface.

- K3 to K5 (130,800 to 148,000) - Within this reach, the tunnel depth varies from 15 to 200 feet below the surface. The section is bounded by two faults and there are several more faults within the section. Bedrock units are repetitive sandstone and claystone units of the Judith River and Claggett formations as previously described.

  Fracturing is significant within 50 to 100 feet of each fault, and groundwater flows may increase slightly, although surface evidence indicates only small seepages in this area. At one location, 5000 feet ahead of K3, the tunnel will traverse a layer of alluvium. The section is in a valley floor, about 500 feet wide, where the Silty and Sandy CLAY (CL) alluvium is up to 25 feet thick.

- K5 to K6 (148,000 to 153,400) - In this reach, bounded by two fault zones, the tunnel will encounter the Eagle formation in the first half and the Claggett formation in the second half. The Eagle formation, in this section, is thick to medium bedded sandstone, with some claystone layers. Some light groundwater flow may be present in the upper portion of the Eagle. The sandstone is fractured, but competent. The Claggett formation will be as described from E3 to F3.

- K6 to F6 (153,400 to 178,400) - The tunnel, at depths of 110 to 175 feet, will encounter the lower, massive sandstone of the Eagle formation. From our test boring DH-3, it is evident that the sandstone will be very competent, dense, and relatively unfractured. Permeability is low, and groundwater flows of 1 to 4 gallons/square foot/day are expected from the more pervious zones.

- F6 to F7 (178,400 to 209,000) - Within this reach, depth to the tunnel varies from about 20 feet to 270 feet. The interbedded sandstone and claystone units of the Claggett formation, dipping about 5 to 10 degrees easterly, will be encountered in the tunnel. The formation is relatively competent and has generally low to very low permeability. The formation will be similar to that described from E3 to F3, except that it is expected to be less fractured and more competent.

- F7 to E8 (209,000 to 223,000) - The tunnel in this section at a maximum depth of 280 feet, will encounter the full thickness of the Judith River sandstone. Bedding dips about 6 to 15 degrees east. The formation contains some interbedded claystone units, but will be mostly massive sandstone. Within this section, groundwater flows on the order of 1 to 3 gallons/square foot/day will be encountered in the more pervious units. The water is expected to be fair quality, except near the contact with the Bearpaw, where the sulfate content will increase.

- F8 area (223,000 to 225,000) - As the tunnel crosses beneath the railroad at the north end of the ring, it will encounter the Bearpaw formation, with similar characteristics as described in the F1 area.

- F8 area (225,000 to 225,800) - In this section the tunnel will encounter the Lennep formation, similar to the reach at F1. Bedding dips about 20 to 25 degrees easterly.

- F8 to F10 (225,800 - 283,000) - Within this final section, at depths of about 60 to 225 feet, the tunnel booster ring and experimental hall areas will encounter the interbedded sandstone, siltstone and claystone units of the Hell Creek/Tullock formation as described in the sections from F10 to E1. Bedding dips vary from about 25 degrees at the north end of the section to about 6 degrees at the south end.

3.2.3.1 **Recap of Profile**

In summary, the tunnel will encounter the various formations as follows:

1.	Hell Creek/Tullock and Lennep	15.8 miles
2.	Bearpaw	5.3 miles
3.	Judith River	13.3 miles
4.	Claggett	13.3 miles
5.	Eagle	5.3 miles

Regarding rock units, the tunnel will be in the following:

Sandstone	68 percent
Sandy Claystone/Siltstone	21 percent
Claystone	7 percent
Bentonitic Claystone (lower 50 feet of Bearpaw)	4 percent

The ring has been located such that no major structures are founded on potentially expansive materials.

3.2.4 Geologic Features

Design and construction of the ring and appurtenances must consider the geologic conditions. The more important of these conditions are as follows:

- Varying rock characteristics - Construction of tunnel and surface structures will encounter six different formations, each having several different rock units. Tunnel and structure design and construction must anticipate these conditions and accommodate the variation in physical and engineering properties, which may change from one rock type (for example claystone) to another (such as sandstone) within a few tens of feet as the construction crosses formational or unit boundaries. For tunnel construction, additional support may be required at formation contacts. A typical range of values for allowable bearing capacity for structures founded on these materials is discussed in Section 3.5 (Northern Engineering & Testing 1957-87). Where the lower zones of the Bearpaw formation are exposed or near surface, the decomposed claystone has significant expansion potential. At depths below about 25 feet (tunnel depth), the claystone has low expansion potential, but will air-slake with prolonged exposure. Construction must be specified and executed to avoid prolonged exposure of these units and avoid significant changes in moisture content.

- Fault zones - Rock units within about 100 feet of each of the several en echelon faults are relatively closely fractured. Within these zones, tunnel design should anticipate some increased groundwater flow (this is discussed further in Geohydrology) as well as additional support.

- Slope stability - Temporary and permanent cut slope stability of the rock units is variable. Typical design slopes for the rock types along the tunnel alignment are discussed in Section 3.5 (Net 1957-87).

- Soil and water corrosivity - Sulfate content of most of the claystone and groundwater within the claystone units is in a range normally considered deleterious to normal strength concrete and must be considered in design of concrete structures. This can be accomplished by relatively simple adjustments of the concrete mix proportions.

3.2.5 Soil Conditions

As previously stated, only limited, local accumulations of soil are present, overlying bedrock along the ring alignment. Most of the surface construction will involve excavated bedrock material, but some of the thin soils will also be involved. These soils are primarily colluvial, derived from decomposition of the underlying bedrock units with transportation on the order of 0 to 10 miles. Many of the characteristics of the bedrock units, therefore, are reflected in the soils. Since sandstone and interbedded sandstone-claystone, make up the majority of the bedrock material, most of the soils are Silty or Clayey SAND (SM or SC). Locally, however, there are accumulations of Lean CLAY and Sandy CLAY (CL), and along the center of Comanche Flat, where the Bearpaw formation is exposed, Fat CLAY (CH). These moderate to highly plastic clays have moisture-sensitive shear strength and generally poor subgrade support properties. Use of the Fat CLAY (CH) should be avoided, except where impermeable materials are needed (NET 1957-87).

With the exception of the Fat CLAY (CH) soil, most of the site soils are fair to good construction materials with fair to good subgrade support properties.

3.3 GEOHYDROLOGY

The Comanche Basin is underlain by at least 12 individual aquifers through approximately 8000 feet of geologic strata. These water-bearing zones include alluvium, sandstone, and carbonate aquifers. Generally, only the upper four aquifers will yield water of sufficient quantity and quality to be used for domestic purposes or stock water. These same uppermost units will be encountered in the proposed SSC tunnel.

Permeability and transmissibility of the formations in the SSC site are low, and aquifers are limited only to certain of the more pervious horizons within the formation. Groundwater volumes are typically adequate for domestic use and livestock supplies and not adequate for irrigation. Groundwater supplies adequate to serve this project could only come from the Madison formation, some 7-8,000 feet below grade, for this reason Billings city water is the recommended water source.

The focus of this section will be on the upper aquifers: Quaternary Alluvium, Lennep (Fox Hills) - Hell Creek formations, Judith River sandstone, and the Eagle sandstone. Other nonproductive and deeper water-bearing strata will be discussed briefly.

3.3.1 Detailed Geohydrologic Characteristics

Detailed evaluations are given for each aquifer within the study area which would be intercepted by the tunnel. The overall hydrologic regime, recharge area, piezometric surface elevation, general water quality and interaction with surface waters will be discussed for each of the uppermost aquifers. Also, primary and secondary permeability of the aquifers and seasonal variations in groundwater levels will be addressed. The static water levels are shown on Figure 3.3-1.

3.3.1.1 Quaternary Alluvium Aquifer

The proposed tunnel location will not intersect saturated alluvium. The maximum thickness of alluvium near the proposed SSC is estimated at 75 feet near the center of the ring 6 to 8 miles from the tunnel.

The alluvium in Comanche Basin is directly connected to surface water. Because this basin is internally drained, runoff from surrounding hills flows into the central area and saturates unconsolidated sediments. Groundwater levels in alluvium fluctuate significantly and range from at or above ground surface in wet seasons to several feet below ground surface after several dry years.

3.3.1.2 Lennep (Fox Hills) - Lower Hell Creek Aquifer

In the site area, the Lennep - Lower Hell Creek formation will be intersected by the tunnel in the northeast perimeter over a length of approximately 16 miles, where it may exceed 400 feet in thickness (Feltis, 1982). Water-bearing sandstone beds may constitute less than one-third of this thickness.

Sandstone units of the upper Cretaceous Lennep (Fox Hills) formation and the lower part of the Hell Creek formation are aquifers in eastern Montana. However, in the site area, this formation has considerably less hydraulic conductivity than in eastern Montana, and water wells in the lower Hell Creek sandstone yield small supplies of potable groundwater. The deeper Lennep sandstone usually provides a relatively good source of water (Hall and Howard, 1923). Domestic water well logs indicate yields ranging up to 30 gpm from 6-inch diameter wells completed in these units. Aquifer tests were completed approximately 9 miles northeast of the proposed site (Montana Bureau of Mines and Geology, 1980). Results are summarized below:

Unit	Transmissivity (feet/day)	Hydraulic Conductivity (gal/square foot/day)
Hell Creek	1.0	0.33
Lennep	3.6	0.46

These quantities are probably provided by primary porosity. During this investigation, in-place permeability tests were conducted at two depths in this formation (see log of test boring DH-8, Appendix 3A) which indicate that in these zones the sandstone is argillaceous and nearly impermeable.

Aquifer recharge probably occurs at outcrops adjacent to the proposed site. Where these units surface along the flanks of numerous anticlines, domes, and other geologic features in central Montana, precipitation and other surface water infiltrates. Minimal recharge may also occur along faults and fractures. Groundwater level fluctuations of 20 feet are not uncommon (Custer, 1976).

3.3.1.3 Judith River Formation Aquifer

The SSC tunnel will intercept the Judith River formation in the north perimeter and the south perimeter for a total distance of approximately 14 miles.

The maximum thickness of the Judith River Formation in the Comanche Basin is about 400 feet, approximately 175 to 200 feet of which may be low volume sandstone aquifers (Feltis, 1982).The Judith River formation is a locally significant aquifer in central Montana, particularly east and northeast of this site, with sandstones producing water of variable quality due to lithologic variations. However, as noted below, conductivity is negligible. No aquifer test reports are available for the Judith River formation in the area of Comanche Basin. Two separate USGS reports for the area indicate that the Judith River formation yields adequate supplies for domestic use (Ellis and Meinzer, 1924, Hall and Howard, 1923). Water-bearing zones within the Judith River formation are usually weakly cemented, medium to coarse, grained sandstone. However, cores taken at the proposed SSC site were moderately to well cemented with significant silica and argillaceous material between sand grains. This formation to the east commonly has a hydraulic conductivity of 0.01 to 10 gal/square foot/day (Freeze and Cherry, 1979). However, at this site packer tests (see Drill Holes [DH-1 and DH-10] in the Appendix 3A) showed the hydraulic conductivity of two zones was negligible, while one zone had a value of 4 gal/square foot/day.

Recharge of Judith River sandstone aquifers occurs where it is exposed to precipitation and surface water. Typically, this occurs along the flanks of numerous domes and anticlines in central Montana. Because these exposures are usually topographically high, the Judith River aquifers are commonly artesian. Depending on distance to recharge, groundwater level fluctuation of up to 20 feet in wells is common between seasons.

3.3.1.4 Eagle Sandstone Aquifer

The Eagle formation is an aquifer in north-central and western south-central Montana. Generally, the Eagle becomes fine-grained east of 108 West Longitude and is not considered a viable aquifer in eastern Montana (Noble, Bergantino, Patter, Sholes, and Schofield, 1982).

At the proposed site, the Eagle formation will be intercepted by the tunnel for approximately five miles along the western perimeter. In the Comanche Basin, the Eagle formation is up to 400 feet thick with 200 to 225 feet of sandstone and the remainder interbedded sandstone, siltstone and claystone (Feltis, 1982). Generally the better aquifer zones within the Eagle are in the upper part and the lower part. The largest reported yield in a domestic well in the area is 15 gpm.

The Town of Broadview obtains its water from the lower part of the Eagle formation with an 8-inch diameter well providing up to 80 gpm (Montana Dept of Health and Environmental Sciences, 1985). Hydraulic conductivity of Eagle sandstone has not been determined by aquifer tests in the Comanche Basin. However, based on grain size distribution, the Eagle probably has a range similar to that of the Judith River formation, 0.01 to 10 gal/square foot/day (11). Packer tests (see DH-3 in Appendix) at the site indicated hydraulic conductivities of 3.2 to 3.8 gal/square foot/day.

Recharge of Eagle sandstone aquifers is the same as for Judith River and Lennep - Hell Creek aquifers: where sandstone units are exposed to surface water. Generally, this recharge occurs along the numerous structural uplifts of central Montana, thus providing artesian conditions within the aquifer with distance from the recharge area. Groundwater level fluctuations in Eagle sandstone aquifers are similar to other aquifers except that the tunnel intercept occurs in the western perimeter where the Eagle is close to recharge; therefore, fluctuations may only amount to a maximum of 10 feet seasonally.

3.3.1.5 Sub-Tunnel Aquifers

Approximately ten other water-bearing formations occur in the 6,000 feet of strata below the Eagle sandstone. None of these units would be intersected by the proposed SSC tunnel. In order of occurrence below the Eagle, these water-bearing strata include the Telegraph Creek formation, the Dakota Sandstone, the Lakota sandstone, the Swift Formation, the Tensleep Formation, the Madison limestone, the Jefferson formation, Cambrian limestones and the Precambrian crystalline rocks. Although some of these formations locally have extremely high hydraulic conductivities due to secondary porosity, depth and poor water quality probably preclude usage in the Comanche Basin.

3.3.2 Groundwater Quality and Local Aquifer Resources

Potential groundwater resources in the vicinity of the site are limited to the four upper aquifers: alluvium, Fox Hills - lower Hell Creek formations, Judith River formation, and Eagle sandstone. Deeper water bearing zones exist but are not used due to poor water quality and excessive drilling depths. Most of the groundwater underlying the proposed SSC is characterized as sodium bicarbonate type with occasional high concentrations of other ions. Total dissolved solids (TDS) varies significantly in near-surface aquifers.

Generally, Judith River formation aquifers have the lowest TDS concentration (400 ppm) and alluvial aquifers have the highest TDS concentration (16,000 ppm). Groundwater quality samples were collected from four wells in the proposed SSC area to confirm historic water quality data. Analytical results are included in the Appendix 3A.

3.3.2.1 Typical Water Quality Results

A range of water quality is present in each aquifer. Analyses of water from the upper four aquifers are presented below with concentrations in parts per million (Hall and Howard, 1923).

	CONSTITUENTS					
Aquifer	TDS	SiO2	Fe	Ca	Mg	Na + K
Alluvial						
Maximum	16283	31	2.0	452	214	1617
Minimum	382	9	Trace	21	1.0	38
Fox Hills - Hell Creek						
Maximum	2675	20	1.7	80	86	925
Minimum	208	4	0.03	.08	3.8	8.5
Judith River						
Maximum	8134	21	5.2	235	159	2438
Minimum	638	5.5	.05	3	1	70
Eagle Sandstone						
Maximum	1549	23	2.2	196	127	307
Minimum	469	13	.24	39	24	70

	HCO_3	SO_4	CL	NO_3	Total Hardness
Alluvial					
Maximum	761	3984	315	6.9	1905
Minimum	229	106	4.0	Trace	57
Fox Hills - Hell Creek					
Maximum	1063	1349	103	3.8	553
Minimum	156	31	2	Trace	14
Judith River					
Maximum	1726	2322	636	5.1	1240
Minimum	340	5.2	5	Trace	16
Eagle Sandstone					
Maximum	593	670	27	4.8	1010
Minimum	271	87	8	.29	196

3.3.2.2 Effect of Proposed SSC on Groundwater

Although local groundwater resources will not likely be used for project needs, other impacts are possible. During tunnel construction, a few (less than 10) downgradient wells that are dependent on thin or susceptible aquifers and that are relatively close to the ring may be affected. This will be a temporary condition until the liner is placed. The groundwater regime will then return to normal. Due to the competence of the strata, subsidence due to dewatering will not occur.

To summarize, groundwater conditions underlying the site are limited to four near-surface low volume aquifers, which include alluvium, Lennep - Hell Creek formation, Judith River formation, and Eagle sandstone. The Judith River formation provides most of the useable domestic groundwater in the Comanche Basin. Groundwater chemistry includes relatively high concentrations of TDS and sporadically high concentrations of sulfate and chloride. Generally, groundwater in this area is a sodium bicarbonate-type water, although ionic concentrations can vary widely depending on the depth of the well intake and by lateral changes in the aquifer.

The quantity of groundwater is limited to the water bearing zones within the formations, and is controlled by primary porosity. Hydraulic conductivities of these water bearing zones are low with typical values in the range of 0.1 to less than 10 gallons/square foot/day.

Groundwater at the depth of tunnel construction will be limited to the more permeable zones and very low volumes, in the range of 1 to 8 gpm for every 100 lineal feet of 12-foot diameter tunnel.

3.3.3 Water-Related Underground Construction Conditions

Within the ring, water-related underground construction conditions will be variable depending upon the formation, depth, faulting, and fracturing. The water conditions are not considered significant, but can be dealt with in the normal course of construction. These conditions are summarized below:

- Eagle Sandstone and Judith River Sandstone. These two formations will be encountered for about 18 miles of the tunnel as described in Section 3.2.2. While water flow is expected within the tunnel bore as it penetrates some zones of these formations, it will be less than 8 gpm/100 feet of tunnel which can be readily controlled within the tunnel bore. Most of the groundwater is expected to be fair quality, except near claystone contacts.

- Lennep (Fox Hills) and Hell Creek Formations. These two formations will be excavated for about 16 miles of the tunnel, and are expected to produce minor groundwater flow from the sandstone units as they are excavated in the tunnel. Flow is expected to be low (one gpm/100 feet of tunnel) and readily controllable within the tunnel bore. Groundwater is expected to have moderate sulfate content.

- Claggett and Bearpaw Formations. The tunnel will intersect these two formations for about 15 miles. Only slight seepage from some of the sandier and/or carbonaceous lenses is expected.

- Fault Zones. Within and adjacent to the faults along four miles of the southwest arc, fracturing of the rock units will result in increased groundwater flows. These flows are expected to be on the order of five gpm/100 feet of tunnel.

- Alluvial Water. Alluvial groundwater will not affect the tunnel.

3.4 SEISMICITY AND FAULTING

While there are a number of faults within and near the site, the last apparent movement is associated with Rocky Mountain building events in late Pliocene time (Alpha and Fanshawe, 1954). The site, and surrounding vicinity, during historic time is an area of relatively slight and rare seismic activity.

3.4.1 Characterization of Site Seismicity

The proposed site is in a region characterized as having low seismicity within recent geological time. Figure 3.4-2 shows the proposed site on the Uniform Building Code seismic map of the United States (UBC, 1982). The site is in Seismic Zone 1, which is the lowest category of seismic activity.

Seismic activity in the geologic past is evidenced in the Lake Basin Fault Zone, which crosses one side of the collider ring; however, no historical earthquakes are associated with the Lake Basin Fault Zone. The zone has been described as being associated with local mountain building events, and having moved most recently during late Pliocene time (Johns, 1982), about 1.6 million years ago. Surface evidence along the zone reveals that near its southeastern boundary it is covered by Pleistocene terrace gravels which have not been displaced (Bergantino, 1980; Rogers and Lee, 1923), decisively placing latest movement older than 10,000 years. During this investigation, geologists found undisplaced Flaxville gravel terrace deposits atop the eroded fault trace, in the area near Huntley, Montana. These Pliocene gravels clearly indicate that no movement has occurred for at least 1.6 million years. It is therefore considered an inactive fault zone. Refer to Section 3.4.3 for a detailed description of the fault zone.

Individual fault lengths are about 6 miles or less. An equation correlating maximum earthquake intensity and surface rupture length indicates an event of 6.3 or less would have produced these faults (Okamoto, 1973).

From 1869 to the present, only a small number of earthquakes have been recorded by instruments or reported by individuals within 100 miles of the site. None of the reported events were strong enough to assign a magnitude; the recorded events ranged in magnitude from 2.8 to 4.0. Figure 3.4-1 presents the inferred epicenter locations, dates and magnitudes of all of the reported and recorded events within a 100-mile radius of the site.

3.4.2 Estimate of Maximum Ground Acceleration Probability

The site is located in UBC Seismic Risk Zone 1. USGS open file Report 82-1033 indicates a probability of 90 percent that horizontal acceleration will not exceed 0.04g within a 50 year period. See Figure 3.4-2 for referenced information.

3.4.3 Local Faults

The faults in the southwest part of the site are all part of an en echelon system known as the Lake Basin Fault Zone. The zone is about 115 miles in length and 6-1/2 miles in width, trending about N.80°.W. from Hardin on the east to the Crazy Mountains on the west. (Alpha and Fanshawe, 1954; Thom, 1923)

Individual faults within the zone are primarily steep and normal, their average strike is about N45°E., and their length about 1 to 5 miles.

Various authors have postulated the latest movement along the zone to be associated with local mountain building events to the west and suggest that the latest movement was Pliocene. During this investigation, mappable evidence has been found to support the conclusion that the latest movement of the zone was in late Pliocene time, about 1.6 million years ago. The area between Huntley and Corinth, northeast of Billings, Montana, has several high level terraces, dated by fossils to be of Oligocene age. Lower terraces consist of Flaxville gravels, Miocene to Pliocene in age, and early to middle Pleistocene terraces are found at the lowest levels of this area.

This area was carefully examined and one fault, approximately 3 miles south of Huntley, Montana, was traced to where it intersected an upper level terrace, dated as late Pliocene in age. The terrace deposit and the upper bedrock contact was not displaced, and no surface expression of the fault remains on the top of the level terrace deposit. A smaller fault, approximately 1 mile south of Corinth (between Huntley and Hardin, Montana), was found to be overlain by early to middle Pleistocene terrace gravels. The contact between the upper bedrock units and the gravel is very distinct, with no offset of the contact. Terrace gravels dated as middle to late Pleistocene in age were mapped near Hardin. During this investigation, geologists carefully examined several of the areas in which the faulted Cretaceous and/or Tertiary formations are faulted and the zone subsequently covered with Pleistocene terrace deposits.

The terrace deposits, as well as the upper weathered bedrock contact surface, were found to be undisplaced at every location examined. The photos on the enclosed plate are typical of the area examined. The above mappable field evidence clearly indicates that no movement of this zone has occurred since early Pliocene time and clearly extends the latest movement of this zone beyond 1.6 million years.

3.4.4 Liquefaction Potential

Liquefaction of soils can occur if four basic conditions exist simultaneously:

- The soil consists of a sand or silt having a grain size distribution within specific limits
- The soil exists in a loose condition
- The soil is saturated
- Strong earth shaking occurs

Evaluation of the soils, water levels and seismicity of this site consistently lead to the conclusion that liquefaction will not occur.

Visual mapping and exploration borings show that soil is generally thin; usually less than ten feet. The soils are predominantly clays and clayey sands which are not within the grain size distribution limits of liquefiable soils. Penetration test "N" values in the soils are normally in the range indicating medium dense for sands and stiff to very stiff for silts or clays. Studies by Seed and Idriss (1971) indicate soils having "N" values within those ranges are not susceptible to liquefaction. None of the exploration borings encountered saturated soils. From field observations it is expected that some localized perched water levels could exist resulting in saturation of some soil layers, but this is not a general condition of the site. Finally, the seismicity of this site is low; it is discussed in Section 3.4.1. From the USGS seismicity map there is a 90 percent probability that a maximum horizontal ground acceleration of 0.04g will not be exceeded within 50 years. Ground accelerations greater than 0.13g are usually required to induce liquefaction (Seed and Idriss, 1971).

3.5 TUNNELING AND UNDERGROUND CONSTRUCTION

As discussed in the previous section, most of the SSC construction will involve sandstone, siltstone, and claystone rock units, with only minor, thin, local alluvium. These units are competent and dip moderately to gently eastward, except for the area within the fault zones, where fracturing is more severe and dips are greater. Groundwater is expected to be present within some of the more permeable zones of the thicker sandstone units, but flow will be small and controllable within the tunnel.

In the following section, the physical and engineering properties of the rock, as they relate to tunnel and open excavation construction, will be discussed. Tunneling and construction methods appropriate to the project, and a section-by-section description of the ring construction is also presented, as well as the use/disposal of the excavated material.

3.5.1 Relevant Soil and Rock Units and Appropriate Construction Methods

The proposed tunnel of the SSC ring lies within six geologic formations as illustrated in Figure 3.2-2. The geologic formations are the Hell Creek/Tullock, Lennep, Bearpaw, Judith River, Claggett, and Eagle formations, described in Section 3.2.3.

Approximately 70 percent of the collider ring lies within formations that are predominantly sandstone, including Eagle, Judith River, Hell Creek, and Lennep. The remaining 30 percent is located in formations that are predominantly claystone and/or siltstone. Two of the formations, the Eagle and Judith River, contain sandstone units which are limited aquifers in the site area. One of the claystone units, the Bearpaw, is bentonitic, in the lower portions. The tunnel is driven into the bentonite units for about 4 percent of its length.

Two construction methods are proposed for this site. A cut-and-cover technique is recommended for areas of relatively shallow depth to the collider ring and the large service, experimental, and booster areas. Tunnel boring is recommended for areas where cover is generally deeper than 50 feet, or due to surface and economic considerations. The rock units around the collider ring are characteristic of soft rock; therefore, soft rock tunneling methods are appropriate for ring construction.

To describe the rock units and their relation to the construction methods for the collider ring, it is convenient to divide the ring into segments and discuss each segment individually. These segments are adopted based on geotechnical properties and the excavation methods. Figure 3.1-4 in the map folder illustrates the segments that are discussed in the following:

- Segment J6 to K2 - Construction will begin within the booster and main campus area early in the schedule. Relatively large volumes of material will be generated from the surface, access, booster and experimental facilities as well as the tunnel, which will be constructed by boring machine in this segment. See Figures 3.5.1 to 3.5.4.

  The construction will take place in the Hell Creek/Tullock formation, and involve primarily sandstone. Typical logs of this material are shown on DH-4 and DH-8 in the Appendix. Groundwater flow on the order of one to two gpm/100 feet of tunnel will be encountered in the deeper sandstone units. This can be readily controlled by pumping within the tunnel and vertical excavations. Due to the thin-bedded nature of the sandstone units, and the low bedding dip angle, some roof bolting will be required, followed by shotcrete support. Support is discussed in more detail in Section 3.5.2.1.

  The excavated material will be predominantly sandstone, suitable for construction of engineered fills for structures and roadways within the campus complex and booster area as well as the access road from Highway 3 to the campus.

- Segment K2 to F1 (11,000 to 28,000) - This segment will encounter Hell Creek/Tullock and Lennep formations, which will be primarily sandstone. Through most of this section the sandstone units have low dip angles, and some zones are relatively thin-bedded, requiring a support system consisting of random rock bolts and shotcrete to prevent roof spalling. Groundwater inflow on the order of one to two gpm/100 feet of tunnel is expected. The last 1500 feet of this section will encounter massive, cross-bedded sandstone with compressive strengths on the order of 2000 to 3000 psi. This reach will not require support.

  All of the excavated sandstone will be suitable for engineered fills within the campus area and the access road from Highway 3 to the campus, which is adjacent to this section.

- Segment F1 + F2 (28,000 to 48,400) - This segment is in the Bearpaw formation, primarily a soft, massive claystone. The unconfined compressive strength of the material is about 200 psi; and the RQD varies from 15 in the upper, partially decomposed zones to 80 in the fresh claystone. At tunnel depth, the moisture content is low (about 9-10%) and the RQD average about 70-75. The logs for Test Borings DH-6 and DH-9 in the Appendix are typical of this material. In this segment, the water inflow is slight, but the claystone is sensitive to change in moisture content and air slaking. Support systems need to be constructed immediately. A full shield tunnel boring machine equipped with a rib expansion track assembly and associated trailing gear is proposed. Sulfate resistant concrete will be necessary in this section.

  Excavated material will decompose to Fat CLAY (CH), which will have to be placed in non-structural embankment areas, and/or used to backfill the cut-cover section described in the following paragraph. The ring has been located so that no major structures are supported on potentially expansive clays.

- Segment E2 to E3 (48,400 to 67,000) - This segment which is predominantly Judith River sandstone, can be excavated in the initial stage of construction by cut and cover techniques. Excavation from this segment can be used for construction and improvement of the access roads to facilitate construction of other parts of the collider ring. The RQD of the material is estimated to be about 90 to 95 percent with an unconfined compressive strength of about 3000 to 4500 psi. A 1:1 (horizontal to vertical) excavation slope is appropriate. The excavation depth varies from 15 feet to about 65 feet. This segment, when completed, can be backfilled with compacted claystone of the Bearpaw formation from the preceding tunneled section between E1+11400 and E2+5000 so that the excavated sandstone can be used elsewhere in the construction. The log for DH-10 is typical for this material.

- Segment F2 to F3 (67,000 to 93,000) - It is in the Claggett formation and consists of interbedded claystone, siltstone, and sandstone, with a preponderance of claystone and siltstone. The unconfined compressive strength of the material at the tunnel elevation is estimated to be 2000 to 5000 psi. This segment will be constructed using a tunnel boring machine. Systematic temporary roof support will be necessary for a portion of this segment due to flat bedding and thin unit thickness. The groundwater inflow will be very small and can be controlled within the tunnel. Excavated material is suitable for embankments for roadways and parking lots.

- Segment F3 to F4 (93,000 to 119,000) - This segment consists mostly of massive Judith River sandstone. Some fracturing is expected near the beginning and end of the segment, adjacent to the two fault zones. The compressive strength of the sandstone is estimated to be about 3000 to 5000 psi. The tunnel will be advanced with a boring machine, with occasional rock bolts for support. Near the fault zone, additional bolting and shotcrete will be needed. Groundwater inflow will be on the order of one to six gpm/100 feet of tunnel and can be controlled within the tunnel. The excavated material will be sandstone, suitable for engineered embankments at the service and experimental areas, access roads and embankments for the west experimental complex.

- Segment F4 to E5 (119,000 to 126,000) - This segment will be bored through claystone of the Bearpaw formation, under similar conditions to those described in Segment E1 (F1 to F2). There will be little or no groundwater flow. Excavated material will decompose to be Fat CLAY (CH), unsuitable for structural fill, but suitable beneath landscape or other non-structural areas.

- Segment E5 to K4 (126,000 to 138,000) - Within this segment the tunnel reaches the ground surface in two small valleys, and intersects six fault zones, including one at each end of the section. Repetitive sections of Bearpaw, Judith River, and Claggett formations will be encountered. Due to the shallow cover and the various large experimental and service units, this segment will be constructed using cut-and cover techniques. Cut slopes of 1:1 to 2:1 (horizontal to vertical) will be appropriate, depending upon materials and excavation depths which varies from 0 to 120 feet. Some water inflow is expected which can be handled by pumping within the excavation. Drill hole 5 is in one of the low areas near a fault in this segment.

  Excavated materials will be used to complete the tunnel cover, and for other structural embankments within the westerly experiment complex.

- Segment K4 to K6 (138,000 to 154,000) - Within this segment, the tunnel will be advanced with boring equipment through sandstone and interbedded sandstone and claystone of the Judith River, Claggett, and Eagle formations. These formations will be moderately fractured, especially near the four fault zones. Rock bolts and shotcrete will be required for roof support. Groundwater flow will be light but controllable within the bore of the tunnel. Support is further described in Section 3.5.2.1.

Excavated material will be sandstone, siltstone, and claystone, with the mixture suitable for engineered embankments within the westerly experiment complex and the service areas.

- Segment K6 to F6 (154,000 to 178,000) - Within this segment, the tunnel will be constructed in the lower units of the Eagle sandstone. Drill Hole 3, the log of which is contained in the Appendix, shows the rock is fairly massive, with compressive strength on the order of 3000 to 4000 psi. The tunnel will be advanced with boring equipment, with little or no support. Groundwater flow is expected to be on the order of two to eight gpm/100 feet of tunnel and controllable within the tunnel bore.

  The excavated material will be excellent for structural fills within the complex and access roads.

- Segment F6 to E7 (178,000 to 188,000) - The tunnel will be bored through interbedded sandstone and siltstone and claystone of the Claggett formation. Water flow is expected to be slight. Systematic rock bolting and shotcrete will be required for roof support in some of the thin bedded, flatly dipping sandstone units. This segment will be similar to Segment F2 to F3.

- Area E7 (188,000 to 191,000) - The tunnel traverses a valley and cover varies from 0 to 50 feet. Cut and Cover methods will be employed, which will both accommodate the topography and provide a surface access to the construction in the northwest arc area. Temporary cut slopes of 1:1 (horizontal to vertical) are appropriate for this cut in the Claggett formation. Test Boring DH-2 is drilled in this area and its log is shown in the Appendix.

- Segment E7 to E8 (191,000 to 209,000) - The tunnel will be bored through the Claggett formation and will be similar to Segment F6 to E7.

- Segment E8 to F8 (209,000 to 223,000) - Within this segment, the tunnel will be bored through Judith River sandstone, requiring only occasional rock bolts for support.

  Groundwater flow is expected, to be on the order of one to six gpm per 100 feet of tunnel and controllable within the bore. The sandstone material excavated from the tunnel is suitable for engineered embankments within the project.

- Area F8 (223,000 to 225,000) - The tunnel segment will be bored through the Bearpaw claystone, except for the center 500 feet, which will be cut-and-cover. The material will be similar to Segment F1-F2. Drill Hole 1 illustrates a typical contact between the Bearpaw and Judith River formations, and DH-9 is typical of the Bearpaw formation.

- Segment F8 to F10 (225,000 to 283,000) - Within the final segment, the tunnel will be advanced by boring through a massive sandstone unit for about 1000 feet (Lennep Formation), then thin-bedded sandstone units with some claystone interbeds. (Hell Creek/Tullock Formation). Unconfined compressive strength is estimated to be about 2000 to 3000 psi. Dip of the beds at the beginning of the segment is about 20 to 25 degrees easterly. Only occasional bolting for support is expected, but as the tunnel proceeds southerly, the dip flattens to about 6 degrees, and the need for roof support will increase to using grouted rock bolts and shotcrete. The booster ring, experimental halls and campus area will be constructed with open cut excavations in these materials. Slight groundwater flow is expected; controllable within the tunnel.

  The excavated material will be suitable for engineered embankments for access roads and within the east campus area.

3.5.2 Physical and Mechanical Rock and Soil Properties Related to Tunneling and Open Excavation

Physical and engineering properties specific to each of the six geologic formations encountered in the tunnel bore are shown on the Logs of Drill Holes DH-1 through DH-7 contained in Appendix 3A. In order, these test borings were drilled in:

Hole	Formation
DH-1	Bearpaw/Judith River
DH-2	Claggett
DH-3	Eagle
DH-4 and DH-8	Hell Creek/Tullock
DH-5	Alluvium/Fault Zone/Claggett
DH-6 and DH-9	Bearpaw
DH-7	Alluvium
DH-10	Judith River

Table 3.5-1 summarizes the properties of the rock units within these formations, as well as a general range of properties for upper Cretaceous and Tertiary sandstones, siltstones, and claystones within 50 miles of the site.

Table 3.5-2 summarizes test results and geologic observations of the various rock units at the site identifying their rock quality classification in accordance with D.U. Deere's methodology. Based upon this information, the bedrock units generally fall in the range of fair to excellent rock, with poor rock in the fault zones.

3.5.2.1 Tunneling Considerations

Tunneling conditions can be summarized as follows:

- Eagle, Judith River, and Lennep Formations. These sandstones are characterized as good to excellent rock. Roof supports will only be required locally, and will consist of grouted rock bolts. This will include about 40 percent of the tunnel.

- Hell Creek/Tullock Formation. These interbedded sandstone and claystone units classify as fair to good rock. Roof supports consisting of rock bolts, in the thin-bedded and/or flatly-dipping zones, will be required. Shotcrete will be required in the claystone units to prevent air slaking. This will account for about 25 percent of the tunnel.

- Claggett and Bearpaw Formations. These interbedded claystone and sandstone units of the Claggett and Massive Claystone of the Bearpaw classify as fair rock. Roof supports, consisting of grouted rock bolts, spaced about 6 feet on center and about 10 feet in length, as well as about 3 to 4 inches of shotcrete, will be required for support. This will include about 30 percent of the tunnel.

- The fractured zones within about 100 feet of the faults classify as poor rock. Within these zones systematic roof supports consisting of grouted rock bolts spaced about 3 to 4 feet on center and about 10 feet in length, as well as 4 to 6 inches of shotcrete, will be required for support. These formations include about 5 percent of the tunnel.

3.5.2.2 Vertical Borings

Rock conditions throughout most of the ring location are very good for winze, raise, and shaft boring equipment and techniques. Minimal supports will be required. The exceptions are the very fractured areas near the fault zones, which wiil require supports, and the Bearpaw Formation which will require supports including immediate shotcrete cover to prevent air-slaking.

3.5.2.3 Cut-and-Cover and Other Excavation

For most of the ring area, bedding orientation is favorable and temporary and permanent slopes will be controlled by the mass properties of the rock. The exception is within the closely spaced fault zone along the southwest side, where fracturing will have an effect on cut slope orientation.

All of the rock and soil materials in the construction area are rippable and open excavations can be made with conventional crawler-tractor/scraper and/or front-end loader/truck methods.

The excavated sandstone and mixtures of sandstone, siltstone and claystone can be readily compacted into engineered embankments, suitable for support of parking lots, streets, access roads and other light to moderately loaded areas. The sandstone is suitable for construction of structural embankments.

The moist density (w) of all of the excavated bedrock units, when compacted to 95 percent of the maximum density as determined by ASTM D698 will be equal to or greater than the 1.8 g/cc (112 pcf) required for the 30 feet of material immediately adjacent to the tunnel bore.

Table 3.5-3 summarizes the excavation, embankment, and other design characteristics of the various rock units which will be excavated. Figures 3.5-1 through 3.5-4 are a conceptual drawings of the service areas around the ring. In Table 3.5-4 we show hardness test results were made at the University of Illinois on rock core samples taken from borings from each of the formations to be encountered on site.

3.5.3 Unique Construction Considerations

The proposed SSC site has, from a geological/geotechnical viewpoint, some obvious advantages. There are also some disadvantages that must be considered in design and construction of the collider. These advantages and disadvantages are summarized below.

3.5.3.1 Geotechnical Advantages

- The proposed collider ring and associated facilities will be constructed almost entirely within rock, resulting in maximum stability, bearing capacity, and durability.

- The rock units, sandstone, siltstone and claystone, are generally characterized as "soft rock" which is relatively easy to excavate with tunnel boring equipment, is generally rippable in open excavation, yet is a stable material, especially in temporary construction excavations. These rock units are very economically excavated and tunnel excavation should advance rapidly.

- About 70 percent of the tunnel is in sandstone which classifies as good to excellent rock for tunneling.

Table 3.5-1

Regional and Site Rock Properties

Formation	Rock Type	Depth (ft.)	Moist Unit Weight (pcf)	Moisture Content (%)	Qu (psi)
Hell Creek/Tullock (Khc/Tt)	Sandstone	22.5 - 23.1	142	10	2150
Hell Creek/Tullock (Khc/Tt)	Claystone	60.0 - 60.4	150	9	190
Hell Creek/Tullock (Khc/Tt)	Sandstone	67.8 - 68.3	149	5	4030
Bearpaw (Kb)	Claystone	25.6 - 25.9	136	17	180
Bearpaw (Kb)	Claystone	54.0 - 54.3	148	12	640
Bearpaw (Kb)	Claystone	55.7 - 56.0	152	10	800
Judith River (Kjr)	Sandstone	91.0 - 91.4	149	6	3180
Judith River (Kjr)	Sandstone	148.5 - 148.8	156	5	5870
Judith River (Kjr)	Sandstone	152.7 - 153.0	155	5	5880
Claggett (Kcl)	Claystone	27.5 - 27.8	155	3	7120
Claggett (Kcl)	Claystone	43.9 - 44.3	157	6	1910
Claggett (Kcl)	Claystone	58.7 - 59.0	154	7	4060
Eagle (Keu)	Sandstone	53.0 - 53.4	141	10	3880

Regional Rock Properties (Middle & Upper Cretaceous within 50 miles of Site)

Formation	Rock Type	Weight (pcf)	Moist Unit Content (%)	Moisture Qu (psi)
Cody (Kc)	Claystone	145 - 154	3 - 13	1110 - 2080
Cody (Kc)	Reworked Claystone	123 - 129	20	11
Eagle (Keu)	Sandstone			6530 - 9380
Telegraph Creek (Ktc)	Claystone	149 - 155	5 - 6	170
Telegraph Creek (Ktc)	Sandstone	155	6	900
Bearpaw (Kb)	Claystone	122 - 123	15 - 28	
Judith River (Kjr)	Sandstone	158	6	980
Judith River (Kjr	Reworked Claystone	117 - 126	18 - 23	3 - 6

Table 3.5-2

Site Rock Properties And Qualities (RQD Method)

Formation Name	Rock Type	Uniaxial Compression Strength, psi	RQD	Joint Spacing, ft.	Joint Condition	Rock Quality*
Hell Creek/ Tullock	Interbedded Claystone Sandstone	190 to 4030	31 - 92	*0.2 to 1.0	Slightly rough surfaces; hard joint wall rock	Fair to Good Rock
Bearpaw Shale	Claystone	180 to 800	15 to 83	*0.2 to 1.0	Soft joint wall rock	Poor to Good Rock
Judith River	Sandstone	5880	85 to 95	10	Slightly rough surfaces; hard joint wall rock, 0.04" separation	Excellent Rock
Claggett	Interbedded Claystone and Sandstone	4060	69 to 96	*0.2 to 1.0	No separation; hard joint wall rock	Fair Rock
Eagle	Sandstone	3880	88 to 100	10	No separation; not continuous; hard joint wall rock	Excellent Rock
Fault Zone	Sandstone and Claystone	1910	25 to 50	0.2 to 1.0	Slickensided sur-surfaces; gouge 0.2" thick	Poor Rock

*Denotes bedding plane separation according to RQD method, D.U. Deere et al.

Table 3.5-3

CONSTRUCTION CHARACTERISTICS - LOCAL BEDROCK UNITS

Formation	Rock Type	Rippability	Cut Slopes* Temp	Perm	Allowable** Bearing, ksf	M/D D698 Optimum Moisture,% / Maximum Dry Density, pcf***	Embankment Slopes
Hell Creek/Tullock (Khc/Tt)	Interbedded Sandstone/Claystone	Good	1:1	2:1	10 - 15	10 - 15 / 110 - 120	2 1/2:1
Lennep (Kl)	Sandstone	Fair	1/2:1	1:1	15 - 30	10 - 15 / 115 - 120	2:1
Bearpaw (Kb)	Claystone	Fair to Good	1:1	3:1	5 - 10	15 - 20 / 105 - 115	3:1
Judith River (Kjr)	Sandstone	Fair	1:1	1 1/2:1	10 - 20	10 - 15 / 115 - 120	2:1
Claggett (Kcl)	Claystone, Sandy Shale, Thin Sandstone	Good	1:1	2:1	5 - 10	10 - 15 / 110 - 120	3:1
Eagle (Keu)	Thin to Massive Sandstone	Fair to Difficult	1/2:1	1:1	15 - 30	10 - 15 / 115 - 125	2:1

*Cut slopes are for relatively fresh bedrock and do not include consideration of local slope-controlling fractures and/or faults.

**Plus one kip per square foot/for each 5 feet of footing depth below a depth of 4 feet.

***Moisture-density is based upon moderately slaked to partially decomposed bedrock.

Table 3.5-4

SUMMARY OF ROCK HARDNESS TESTS
UNIVERSITY OF ILLINOIS

Drill Hole	Depth	Formation	Rock Type	Hammer Rebound Values, H_R	Abrasive Hardness, H_A	Total Hardness, H_T
DH-1	87.0-88.0	Judith River	SANDSTONE	27.0	0.32	15.3
DH-1	152.7-153.5	Judith River	CLAYSTONE	32.3	0.43	21.2
DH-2	20.5-21.4	Claggett	SANDSTONE	28.1	-.30	15.3
DH-2	55.2-56.0	Claggett	CLAYSTONE	27.1	-.33	15.5
DH-3	52.1-52.9	Eagle	SANDSTONE	22.7	0.21	10.4
DH-3	204.0-204.7	Eagle	SANDSTONE	26.9	0.25	13.5
DH-4	26.6-27.0	Hell Creek/Tullock	SANDSTONE	42.7	1.436	51.2
DH-4	59.2-59.9	Hell Creek/Tullock	CLAYSTONE	25.7	0.195	11.3
DH-6	34.7-35.3	Bearpaw	CLAYSTONE	20.3	0.244	10.0
DH-6	52.7-53.4	Bearpaw	CLAYSTONE	23.0	0.284	12.3

- Groundwater flows within the tunnel and excavations will be small and readily controllable.

- Eighty to 90 percent of the excavated materials will be suitable for engineered and/or structural embankments.

- The site topography is relatively flat, yet rolls enough to provide for surface access (cut-and-cover) at various critical locations around the ring, giving natural access for tunneling and thereby expediting construction.

- The tunnel bore will intersect all fault zones nearly perpendicular, minimizing the effect on stability.

- The site is seismically inactive.

3.5.3.2 Geotechnical Disadvantages

- About 10 percent of the ring is in Bearpaw claystone, and about 25 percent of the claystone within this Formation is bentonitic. This will require some consideration in tunnel design and construction, but can be accounted for in normal construction practices.

3.5.4 Recommended Construction Techniques

Two different methods of construction are proposed for the tunnel at this site. A cut and cover technique is recommended for areas where depth is generally less than 50 feet, and for large experimental service and booster areas. Underground tunnel boring is recommended for areas where cut and cover was considered uneconomical or impractical.

The surface excavating equipment proposed is typical of equipment utilized in the surface mining and construction industry, including crawler tractors and scrapers or front-end loaders and trucks. The tunnel boring equipment is typical of shield tunneling equipment being used in similar soft-rock underground applications.

The cut and cover technique is proposed for about 20 percent of the total length of the collider ring. The cut slopes are estimated to vary from 1:1 to 2:1 (horizontal to vertical) depending on the material encountered. Front-end loaders and trucks and/or scrapers are appropriate to excavate the cut and cover areas. Scrapers, bulldozers, and compactors will replace backfill and compact the trench after the precast or cast-in-place concrete line is constructed. Open cut excavation is proposed for the collision and access halls. A slope of 1:1 is estimated to be suitable for these excavations. These experimental halls will be built at a depth approximately 30 feet below the centerline of the main collider ring (i.e. at a depth of about 125 feet below the ground surface) and must support loads

up to 9 tons/square foot. At this depth, the overburden pressure being excavated is approximately equal to 125 feet of rock or about 9 tons/square foot. Therefore, the rock at that depth, with an unconfined compression strength of about 2000 to 5000 psi, will readily support the required load without shear failure or and it will be possible to balance load and settlement to accommodate the anticipated structural conditions.

Tunneling is proposed for about 80 percent of the main collider ring. The rock encountered in the ring area is characterized as soft rock. A wheel excavator tunnel boring machine with a diameter of about 12 feet will be used to excavate the rock. The cutterhead, contained within a shield, is equipped with soft rock cutting teeth. The muck which is removed from the face falls to the bottom of the shield where it will be moved to the back of the tunnel boring machines by means of horizontal mucking arms and conveyors, buckets, belt drives, or similar equipment. Support, as required, will be placed behind the boring operation.

A permanent liner will be required in the final design for all of the tunnel length and will consist of precast concrete segments or slip formed concrete. The permanent liner should follow closely behind the excavation for most parts of the tunnel particularly in the Bearpaw formation. A railroad tunnel driven in the Claggett formation (25 percent of collider ring goes through this formation) about four miles Northwest of the site was examined. The following is a summary of our observations and findings. Photographs are included in Appendix 3A.

- Name and Location: Painted Robe Tunnel in Golden Valley County, Montana.

- Dimensions: Approximately 1000 feet long; Horseshoe shape; 12 feet wide by 18 feet high.

- Type of Liner: Cast-in-place unreinforced concrete. This tunnel has been in service since 1920. Inspection of the tunnel revealed that there is no apparent structural distress to the tunnel due to approximately 70 feet of overburden rock. Minor concrete spalling was observed in the roof at the concrete joints due to the deteriorating effect of sulfate in groundwater.

Ten rock cores were selected, typical of all of the various rock units encountered by the SSC tunnel, and tested for Schmidt rebound hardness, Hr, and abrasion hardness, Ha. From these data, total hardness, Ht, was determined to be in the range of 11 to 50. A copy of these test results is shown on Table 3.5-4.

Using correlation data from Tarkoy's thesis , updated by Dr. Alfred Hendron of the University of Illinois, a correlation was made between total hardness and instantaneous tunneling rate for single full-face, wheel type tunnel boring machine (TBM). An instantaneous advance rate of 20-30 feet per hour is expected.

Considering that the TBM was utilized 33 percent of the time, a three-shift daily advance rate is conservatively estimated to range from 160 to 240 feet per day for a single TBM. Because of the magnitude of this project, multiple tunnel boring machines will be utilized. In the cut and cover sections, production rates of 2000-3000 cubic yards per day are common in these rock types.

3.5.5 Spoil Sites

Whether open cut-and-cover or bored tunnel, construction of the ring and appurtenances will generate a significant quantity of material. The nature and properties of this material is discussed elsewhere in the section, but at least two-thirds of it will have properties similar to Clayey and/or Silty SAND (SC or SM). With the exception of the high-plasticity Fat CLAY (CH) soils derived from the bentonitic layers (about 4 percent of the total excavation), the material can be compacted into structural embankments suitable for all but the heaviest structural loads, and the excavated sandstone is suitable for structural fills. With suitable surfacing thickness to accommodate anticipated traffic volumes and loads, embankments for access roads, internal streets, parking lots and service areas can be constructed from these materials.

To plan for the disposal of the excavated material, the volume was estimated and an appropriate swell factor was applied to account for an increase from in-situ to embankment. The topography was examined at the east and west campuses and at the individual service areas. Most, if not all, of the excess quantities from the ring excavation will be needed to construct the campuses and service areas. However, if these features do not require all of the excavated materials, the embankments for the various access roads will certainly require all that remains. It was concluded that all of the material can be used within 5 miles of excavation or tunnel access point with the average surface haul being less than two miles. These conclusions were subsequently field verified by re-examining the site, and identifying the location and extent of required embankment construction.

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REGIONAL RESOURCES

The proposed Comanche Basin site, approximately 20 miles from Billings, Montana, has an excellent regional resource base to support the construction and operation of the SSC. Located in south central Montana, the area is surrounded on three sides by scenic mountain ranges, creating a blend of plains and mountain geographies. Billings, the largest city in Montana (Metro population 120,000), offers both an excellent quality of life and a dynamic business environment to support the SSC (see Billings Brochure, Appendix 4A). From its beginnings as a rail head for the Northern Pacific, Billings has become a cosmopolitan city whose population has nearly doubled every 30 years. The central hub for the distribution of goods and services to a region in excess of 125,000 square miles, Billings' primary trade territory is one of the largest in the U.S.

Billings is the major trade center in the region. It has exceptional air, rail, and highway transportation networks. Billings Logan International Airport, the largest commercial airport within five states, is just minutes from both the site and the city's central downtown business district. The community's public transportation system and airport shuttle services can deliver visitors to the site within 25 minutes. In addition, well-maintained roads and rail trackage bisect the site, providing easy access to the site, particularly for delivery of the freight required to construct the SSC and supporting facilities.

Recent construction nearby of four large-scale coal-fired electrical generating plants, surface and underground mining projects, as well as continued commercial building construction, has created a well trained, productive and skilled labor force and immediate access to natural and manufactured construction materials. The area has quality housing for the estimated 10,000 new residents brought in by the SSC project.

Billings is a also the medical and educational center for the region. The city's medical community provides the most advanced health care services in a four-state area. One of the six Montana State University system units is located in Billings, as well as a private college and a modern vocational technical center. Satellite communications systems among higher-education facilities in the state assure quality education through a unique cooperative effort on the part of all colleges and universities in Montana. The state's public education system ranks among the best in the country and is rated third in terms of overall student achievement.

Recreational and cultural opportunities in the area are among the nation's finest. Nearby Yellowstone National Park and the northern Rocky Mountains provide outstanding outdoor recreation, including acres of national forest for family expeditions. Skiing, whitewater rafting, fishing, hiking, camping and golf are among the many outdoor activities available. The recently completed $5.2 million Alberta Bair Theater for the Performing Arts is home to the Billings symphony orchestra and host to national, international and regional theatrical productions, dance, opera, concerts, and other fine arts performances. The region also has a rich and colorful Western heritage featuring folk festivals, Native American events, ethnic fairs, rodeos and western barbeques.

4.1 ACCESSIBILITY OF AIRPORT

Billings Logan International Airport is the largest commercial airport in a five-state area and serves as the major hub for the region's air traffic. Located approximately 20 miles from the center of the site and 2 miles from Billings' central downtown business district, the airport is ideally situated to serve the SSC staff, members of their families, and visitors. Serviced by four international airlines and a regional commuter line, the airport offers direct connections to cities throughout the U.S. and Canada. The airport has been cited by the American Association of Airport Executives for its operations record and has received national awards for its outstanding winter service record (Binford, 1987).

4.1.1 Existing Facilities

The airport complex is centrally located between the site (25-minute drive time) and downtown Billings (4 minutes). Encompassing 2,200 acres of property, the airport complex includes the airfield (elevation 3,567 feet above mean sea level), a main terminal building, air traffic control (Salt Lake Air Route Traffic Control Center), four runways, fixed base operators with a full range of flight services, air cargo and airmail facilities, air ambulance emergency transport, and the National Weather Service. The airport has six air carrier aircraft gate positions and ramp space for several commuter aircraft. All types of modern commercial jet aircraft can be accomodated.

Aircraft gates include automated passenger loading bridges. Increasd air traffic from the SSC project can be easily absorbed by the complex's excess runway capacity. As shown on Table 4.1-1, the airport's runways currently accommodate 110,000 actual aircraft operations yearly and are designed to handle up to 350,000 aircraft operations annually (City of Billings).

4.2 HIGHWAYS, STREETS, ROADS AND RAILROADS

Excellent rail and highway networks have made Billings the major hub for the distribution of goods and services to a trade region encompassing 125,000 square miles. The site is bisected by the Burlington Northern Railroad and by Montana State Highway 3 and is easily accessed by three federal highways. Served by the interstate highway system from the south, east and west, the SSC campus is accessible to all points in the continental U.S. In addition, several well maintained county roads provide a good network of access routes within the site area.

Montana is well served by more than 6,500 intrastate, interstate and international commercial motor carriers. In the region of the SSC site, there are 60 interstate and intrastate trucking firms that travel to and from the Billings area.

4.2.1 Transportation Characteristics

4.2.1.1 Highways, Streets, Roads

The site is bisected by Highway 3, an established truck route able to accommodate maximum capacity loads. A 23-mile stretch of this road connects the site to the City of Billings. As the major industrial hub in the region, Billings is the meeting point for all primary road systems including I-94, the direct route to Chicago and to the Midwest, and I-90, which provides a direct route to Montana State University in Bozeman; the University of Montana in Missoula; and the Pacific Northwest and northern and central Rocky Mountain states to the west and south. Figure 4.2-1 shows major routes accessing the site, as well as Billings, in relation to major interstate highways.

Direct primary access to the site is provided by State Highway 3; however, U.S. highways 87, 310, and 212 provide alternate connecting routes from the site to Billings and other communities within Montana, as well as Wyoming, North Dakota and South Dakota. (See Table 4.2-1 and Figure 4.2-2 for travel times and distances to major cities.)

Trucks shipping materials in and out of the site will use the interstate system to the south of Billings. The interstate system connects with Highway 3 by US 87. Major highways which access the Comanche Basin are surfaced with asphalt. (Table 4.2-2 summarizes conditions and excess capacity available on major site access routes.) Highway 3 and US 87 are both four-lane highways in the urban areas, with mostly two-lane sections in rural and urban portions of the truck routes. These require flag cars for

vehicles with widths over 12 feet in the two-lane sections and over 14 feet in the four-lane sections. Vehicles longer than 100 feet require front and rear flag cars. There are no restrictive weight limitations, and the roadway surfaces currently handle long-bed (HS-20- 44 design) vehicles. No problems are expected with truck routes accommodating increased traffic from the project. (VanMil, 1987). Montana is in the process of improving all urban interchanges on the truck routes, which will allow greater turning capability these vehicles (1989 projected completion). All intersections in the vicinity the site are now capable of accommodating over-height vehicles (Dusek, 198 VanMil, 1987).

Existing county access roads within the site area generally run along section lines and are well maintained gravel roads in good condition. Figure 4.2-3 illustrates the location of the existing grid of county access roads within the site, as well as planned improvements for these roads.

4.2.1.2 Railroads

Well maintained rail lines and comprehensive rail freight services have established Billings as the major rail termination and origination center in a five-state area. Billings is an important hub in the extensive Burlington Northern (BN) Railroad network, a Class One (more than $50 million in gross operating revenue annually) rail system that serves 25 states and 2 Canadian provinces (Montana Rail Plan, 1984).

The trackage running through the site (known as the Mossmain Line) carries a Federal Railroad Administration (FRA) safety classification of four, the highest safety classification possible, and allows maximum speeds of up to 6(miles per hour through the Comanche Basin site. According to the transportation division of the Montana Public Service Commission and Burlington Northern, the newly renovated line is in "excellent" condition and capable of handling in excess of a 263,000 pounds normal weight restriction (Budt, 1987). Burlington Northern is nearing completion of a 5-year, $10 million program to upgrade this line (Keim, 1987).

The towns of Broadview and Comanche, both at the center of the site, have existing rail sidings with loading and unloading capabilities available to serve the site. Existing facilities do not include platforms and depots, but a commitment from BN assures these services will be added should business dictate (Keim, 1987).

Table 4.2-1

Highway Distances and Driving Times to the Comanche Basin

City	Mileage	Driving Time
Billings	23	20-25 minutes
Bozeman - MSU	150	2 hrs, 20 min
Butte	224	3 hrs, 25 min
Calgary	549	8 hrs, 30 min
Casper	280	4 hrs, 15 min
Denver	555	8 hrs, 30 min
Missoula - U of MT	339	5 hrs, 15 min
Rapid City	320	5 hrs
Salt Lake City	549	8 hrs, 30 min

Table 4.2-2

Characteristics of Major Routes Serving the Site

Route	Facility	Lanes	Capacity VEH/HR)	Volume (VEH/DA)	Level of Service
MT 3 (rural)	undivided, primary	2	1,810	1,450 1,800	A-B
302 E. (rural) secondary	undivided,	2	1,685	300	A
302 W. (rural) secondary	undivided	2	1,816	245	A
US 87 (urban) Lockwood Interchange	div. arterial	4	3,800	---	B
US 87 (urban) arterial East Bridge	undivided	2	2,300	16,380	B
US 87 (urban) Main Street to Wicks Lane	div. arterial	6	4,000-8,000	23,000-36,000*	B-D
US 87 (urban) Wicks Lane Roundup Road	div. arterial	4	3,000-4,000	12,970	A-C
US87 (rural) Roundup Road North (47 miles)	undiv. primary	2	1,442-2,683	1,780	A-C
FAU 1014 (urban) Airport Roads	undiv. arterial	2	1,600-2,600	7,570	B

*Peak hours include highly directional morning and evening peak drive times.

Typical Examples of Level of Service (LOS):

Rural LOS:
A = approx. 33% of Capacity A = (0-5 second stop per vehicle (SPV))
B = approx. 50% of Capacity B = (5.1-15 second SPV)
C = approx. 65% of Capacity C = (15.1-25 second SPV)
D = approx. 80% of Capacity D = (25.1-40 second SPV)
E = approx. 100% of Capacity E = (40.1-60 second SPV)
F = over capacity F (anything over 60 seconds)

Source: Annual Counting Program, Mt Dept. of Highways. LOS and capacity information obtained from 1985 Highway Capacity Manual.

Also facilitating the transfer of freight for the site is BN's intermodal hub located in Billings, only 23 miles from the site. Eighteen thousand truckloads of freight originate or terminate at the intermodal hub each month. BN completed a multi-million-dollar expansion of this facility in 1987, allowing the hub to easily accommodate the projected freight needs of the project. BN also has under contract trucking firms that can deliver inbound/outbound freight from the hub to the site within two hours (Ackerman, 1987).

BN recently invested $9.4 million in a modern switching yard in Laurel, 18 miles west of Billings. Facilities include computerized switching and a state-of-the-art welded rail plant that provides year-round maintenance materials to rail lines nationwide.

4.2.1.3 Truck Freight/Hauling Capabilities

Approximately 60 trucking firms include Billings on their regular routes. Types of hauling include heavy freight, liquid and dry bulk and major motor freight. Several specialized carriers also haul Montana commodities such as petroleum products, timber, livestock and grain to areas outside of the state. The area's trucking business also includes five trucking transportation brokers.

4.2.2 Improvements Needed to Support Construction and Operation

4.4 INDUSTRIAL AND CONSTRUCTION RESOURCES

A skilled, experienced labor force and a diversified economy provide Billings with one of the best industrial and construction resource bases in the Northwest. These resources are immediately available to support construction and operation of the SSC project.

The steady growth of Billings over the past 35 years has resulted in a constantly expanding labor force, both in terms of size and diversification of skills. Large-scale mining and construction projects, including the construction of four coal-fired generating plants, the Minuteman missile sites, and major oil and coal exploration operations are contributing factors to the immediate accessibility of well developed construction resources and a highly mobile work force. These large-scale projects using Montana resources and labor demonstrate that the area has the infrastructure necessary to handle a construction project of the magnitude of the SSC complex. In addition, continuous commercial construction throughout the Billings area since 1970 has further developed a skilled labor force, as well as a large supply of local construction and industrial materials. Tables 4.4-1 and 4.4-2 profile a sampling of recent large-scale construction projects in the area.

High technology firms with experience relating to SSC construction needs are also based in the area. Both primary and secondary support industries exist in Billings with the capacity to service the construction and operational demands of the project.

4.4.1 Regional Industrial and Construction Resource Base

4.4.1.1 Construction Resources

The number and magnitude of past construction projects within a 300-mile radius of Billings are key factors in the development of the area's industrial and construction resource base. For example, four coal-fired generating plants located in Colstrip, Montana, were constructed between 1970 and 1986. The total cost of the project was $2 billion. Serviced largely from Billings, the project was not only under budget from the first definitive estimate, but also on schedule throughout construction. During peak construction, 2,850 people were employed; 80 percent of those employed were drawn from the Montana and immediate region labor pools. (Table 4.4-2 shows a breakdown of labor skills required to construct these units.)

Within 23 miles of the site are suppliers of a full range of construction materials and equipment, operations equipment, and industrial gases and solvents required by the project. Local supply of these materials assures immediate availability, service capability, and competitive costs. Unlimited reserves of high quality gravel and aggregate materials suitable for concrete are available within a 50-mile radius of the site. Major national cement manufacturers are based in Montana (Lockrem, 1987). Available materials and capacity include the local production of approximately 700,000 tons per year of cement and in excess of 1 million tons per year of aggregate materials. Table 4.4-3 gives additional examples of area suppliers and materials.

Montana compares very favorably to most other states nationwide in construction materials cost. The costs of most building materials in the region of the site are considerably lower than those of other states. For example, the average cost of a 1-ton unit of 1 1/2-inch gravel in Billings is $5.00 as opposed to $8.25 for the same amount in Denver. Figure 4.4-1 provides additional materials cost comparisons (Engineering News Record, 1987).

4.4.1.2 Industrial Resources

Billings has long been the major heavy equipment distributor and maintenance center for the Northern Great Plains region's mining, oil and gas, agricultural and construction industries. Most of the nation's largest equipment manufacturers and vendors have Montana distribution services and regional warehouses in Billings and provide overnight delivery of any specialized parts or equipment.

Electrical and electronic equipment and fabrication needs can be met through local suppliers of major electrical equipment. Industrial solvents and related petroleum products are readily available from the three major oil and gas refineries located in Yellowstone County. Structural and fabricated steel can also be supplied from several manufacturers in the area (Lockrem, 1987). Bulk quantities of compressed and liquefied gases (He2 N2, O2) are presently available in Billings. Short-range plans of both hospitals include installation of a pumping station that will further increase the volume of liquid helium available. Billings is only 280 miles away from the world's third largest supply of liquid helium (Exxon, Airoco Industrial Gases, Shute Creek, Wyoming), which can be transported within a day to the site (Kornbluth, 1987).

4.4.1.3 High Technology Resources

The industrial technology resources in the region surrounding the site are complex and diversified. These include high technology manufacturers and numerous computer programming, data handling, and industrial process control firms. Specialized technology services in the region have supported the development and construction of the experimental MHD (magnetohydrodynamics) facility in Butte, as well as the numerous sophisticated mining, synthetic fuels, and power generation facilities in the region. Resources range from high speed data acquisition to the computerized routing of power for consumer use. Technology-based specialities in the region include computerized power control, custom hardware and software applications, advanced environmental monitoring systems, high speed data acquisition, and manufacture of industrial controllers. Research facilities and consultants are available from many private firms and all six units of the Montana university system.

Technical services located in Billings also include numerous computer hardware and software sales, service, and design firms, including both the sales and field support center for Digital Equipment Corporation (second-largest computer manufacturing company worldwide) for a five-state region.

4.4.2 Labor and Wages

Ranking fourth in the nation for worker productivity, the Billings labor force is one of the best in the country. Employers have found the local labor pool to be both skilled in all areas of construction and mining, and hardworking (Inc. Magazine, 1984). In addition, the steady growth of Billings over the past 35 years has resulted in a labor force constantly expanding to meet the needs of large-scale construction projects (Montana Department of Commerce, 1984).

4.4.2.1 Labor Force

There are an estimated 64,500 persons in the local labor force. Table 4.4-4 shows local employment by industry for 1984. Along with the labor pool in the immediate vicinity of the site, there are additional sources of available labor throughout the region. Although the area's work force is highly skilled in all aspects of large-scale construction, additional training in specialized skill areas are available through the Montana Private Industry Council. The council provides training and upgrading programs which are closely coordinated with economic development activities in the state. Through the council, workers are sought out and trained for any new or expanding industry in Montana at no cost to the employer. On-the-job and classroom training are provided as well.

One out of every seven workers in Montana belongs to a union (Montana Department of Labor & Industry, 1987). Many of the major construction jobs in the area (Colstrip, Decker mines, Minuteman missile construction) were 100 percent union built. Specialized training is provided by the union in the areas of construction, mining and manufacturing.

As indicated in the July 13, 1987 letter of support from the Montana State AFL-CIO (Appendix 4B), the Southeastern Montana Building and Construction Trades Council has proposed that any labor agreement covering the construction of the SSC be a "project" agreement. Such an agreement would be negotiated by the local unions to cover the entire construction phase and therefore provide for a stable workforce and time-frame for completion of work. The project agreement would also minimize potential labor conflict and establish project-duration conditions of employment. Also included in the Montana State AFL-CIO letter is an estimate of the skilled labor force currently available to work on the SSC project.

Native Americans in the area near the site also offer a potential source of skilled labor. Extensive mining and construction projects in recent years have enabled area tribal members to develop construction and mining-related skills, including welding, heavy equipment operation, electrical, and construction. Native Americans make up 2.8 percent of the employees involved in major private construction projects in the area. In addition, tribal members comprise nearly 100 percent of Bureau of Indian Affairs (BIA) and federally sponsored highway and construction projects on the region's reservations (Crow and Northern Cheyenne). Because of high unemployment on the reservations, there is an immediate availability of skilled laborers. Additional specialized construction training is available to tribal members through several BIA programs. Table 4.5-2 shows the ethnic composition of the area's work force.

Along with the local labor force, the site location provides the opportunity to tap the labor pools from the nearby states of Idaho, Wyoming and North and South Dakota. The regional construction labor pool is very mobile and is accustomed to relocating on a temporary basis near job opportunities. Billings has the capacity to serve this type of temporary labor force and has done so on numerous projects, including the recent construction of the Colstrip coal-fired generating plants and the Minuteman missile.

4.4.2.2 Worker Productivity

Productivity of Montana workers is significantly higher than the national average. According to a national survey, Montana's 1984 worker productivity was at $66,300 value added per worker per year, a 16 percent increase over the previous year. This was well above the national median, which rose 7 percent to only $39,600, making Montana's worker productivity fourth highest in the nation (Inc. Magazine, 1984). In addition to being productive, Montana workers are well educated. Seventy-five percent of the state's workforce over the age of 25 has at least a high school education (Bureau of Census, 1980).

A 1985 comparison of national Utility Data Institute (UDI) data regarding productivity in construction of large-scale (400 to 1000 MW range) coal-fired power generating facilities showed that Montana's worker productivity was 10.5 percent better than the national average for similar projects during the recent construction of the Colstrip Unit 3 generating facility east of Billings (UDI, 1985; MPC, 1985). Labor productivity categories reviewed in this comparison are directly relevant to the construction needs of the SSC. These categories include: Concrete in Place, Rebar Installation, Formwork Installation, Piping, Large Pipe Erection, Large Pipe Welds, Wire and Cable Installation, and Conduit Installation.

4.4.2.3 Prevailing Wage Rates

Montana has competitive base rates for construction trades and is below the national average wage in most areas. Montana's wage scale overall is about 12 percent less than the national average. (Montana Department of Commerce, 1985). For example, the wage rate (with fringes) for a carpenter in Billings is currently $15.76, while in Denver the wage rate is $17.20. Additional comparison of wage rates for key construction trades is provided in Figure 4.4-2. The listing is based on current union scale for the area, including fringe benefits (Montana Department of Labor and Industry, 1987). Since the SSC project will most likely be a union-built project (per the Davis-Bacon Act), these average prevailing wage rates compare even more favorably with those of many other states, where prevailing wage levels often reflect substantial non-union construction activity.

4.5.3.2 Employment Opportunities

A wide range of employment opportunities throughout the area surrounding the SSC site is available for family members of SSC employees. Job opportunities in advanced technology are available, including computer programming, engineering, computer applications, and research and development. Employment is also available in all professional fields including education, medicine, technology and retail. To facilitate the job searching process for family members of SSC employees, the Billings Area Chamber of Commerce is developing an employment assistance program (Appendix 4B). Several social service agencies in Yellowstone County also have job assistance programs to meet the employment needs of new residents.

4.5.4 Federal Fair Employment Practices, Equal Employment Opportunities and Open Housing Practices

The Montana Human Rights Commission regulates and enforces Equal Employment Opportunity (EEO) laws and fair housing laws within the state. The Commission is fully certified by the federal Equal Employment Opportunity Commission (EEOC), and is acknowledged nationally for being open and fair in the areas of equal employment and open housing. Montana's Constitution, laws, and practices are broader than federal law in protecting the rights of Montana citizens (EEOC, 1987). State law requires contractors working with the state to adopt EEO hiring policies. In addition, Montana's human rights laws are among the most progressive in the country and include special protection for pregnant workers, the handicapped, and employees of all ages, as well as provisions for educational and on-the-job-training programs. Open housing laws are also enforced to protect against discriminatory treatment when buying or renting housing or property (Montana Constitution). (Refer to Table 4.5-2 for a breakdown of employed persons by ethnic group.)

4.5.4.1 Inquiries and Complaints

Complaint response and investigation by the Montana Human Rights Commission staff is timely and efficient. The Commission received 1,459 discrimination inquiries in fiscal year 1986-87. Of these, 308 were opened as new cases. Table 4.5-3 shows the number of cases opened, closed and pending for fiscal years 1980- 81 to 1986-87. The table shows an increase in the cases closed and a decrease in the number of cases opened, closed and pending for fiscal years 1980-81 to 1986-87. The table shows an increase in the cases closed and a decrease in the total discrimination cases pending since 1982. Most of the inquiries and cases pending are dealt with on the state level with less than 200 annually being referred for oversight to the federal enforcement agencies (EEOC, 1987; MacIntyre, 1987).

4.5.4.2 Equal Job Training Opportunities

Equal job training opportunities are also integral to the Montana anti-discrimination statutes, which require that vocational guidance programs and on-the-job training within governmental agencies be open to all persons. The programs are conducted to encourage the full development of skills and focus special attention on culturally deprived, educationally handicapped and economically disadvantaged persons. In addition, the law encourages expansion of training opportunities in segments of the labor force which need an upgrading of skills. Similar training programs are available for Native Americans through the Bureau of Indian Affairs and through the Montana AFL-CIO which offers apprenticeships and on-site training programs to union members (Bureau of Indian Affairs, 1984; Montana State Job Service, 1987).

VOLUME 5

ENVIRONMENT

The Comanche Basin site is situated in an internally drained basin among the rolling plains of south-central Montana, near the major regional center of Billings. The climate is continental, but moderated by the Rocky Mountains to the west, so that local weather conditions are generally temperate. It is a sparsely populated rural area characterized by mid-grass prairie, much of which is dryland farmed or grazed by livestock. Large rocky outcrops, with stands of ponderosa pine, provide visual relief. Native vegetation and animal species are generally typical of those found throughout eastern Montana. The basin contains several small ponds that support a variety of waterfowl.

Overall environmental impacts at the Comanche Basin site are expected to be minimal. Impacts on the natural environment will be temporary and localized, affecting resources that are common and abundant in the region. Some short- and long-term impacts to the human environment are inevitable; however, the socioeconomic benefits derived from the construction and operation of the SSC outweigh the unavoidable negative effects.

No significant impacts have been identified that would adversely affect the project's ability to comply with all applicable environmental regulations/requirements or the timely acquisition of necessary permits and other authorizations. No unusual and/or expensive mitigation measures are anticipated.

5.1 WETLANDS

The U.S. Geological Survey 1:24,000 scale topographic maps show no marshes within the site. Other surface water bodies in the internally drained basin, however, do exhibit some of the features that are characteristic of wetlands (See Figure 5.2-1). Existing literature as well as field reconnaissance in May through July 1987, and an analysis of aerial photographs of the site, indicate that many of the ephemeral, intermittent and perennial small ponds and potholes in the basin support vegetation and aquatic life that require saturated or seasonally saturated soil conditions for growth and reproduction (Wilson, 1987). These water features may constitute wetlands as defined by DOE in its regulations implementing Executive Order 11990 - Protection of Wetlands (10 CFR 1022 et seq.).

A thorough search of existing wetlands information available from state and federal agencies, including the U.S. Fish and Wildlife Service, Bureau of Land Management, Soil Conservation Service, Montana Department of Natural Resources and Conservation, Montana Department of Fish, Wildlife and Parks, and Montana Department of State Lands, has shown that little published data on wetlands exists for the Comanche Basin area (Wilson, 1987; Bierback, 1987). Thus, although preliminary field reconnaissance and successive-year aerial photograph analysis indicate that wetlands in this semi-arid basin are not extensive or unique to the site area, a formal wetlands assessment will be required to determine the precise extent and location of any wetland features which might qualify for protection under DOE Executive Order 11990. Based on the area's topography, it is likely that many of the surface water features qualifying as wetlands will be located within the center of the ring.

The ponds and potholes within the Comanche Basin that exhibit wetlands characteristics are discussed with other surface water features in Section 5.2.1; another large depression in the middle of the basin that is occasionally flooded, labeled the Comanche Flat, is discussed in Section 5.2.4.

5.2 SURFACE WATER

5.2.1 Major Drainage Basins and Surface Water Features

The SSC facility will be largely within the drainage of the Comanche Basin, with portions of the SSC ring also intersecting ephemeral streams on the fringes of the Lake Basin and Painted Robe Creek watersheds to the west (Figure 5.2-1).

The 230-square-mile Comanche Basin is a closed, internally drained basin, with 198 permanent or intermittent small ponds, agricultural impoundments, and potholes and 46 ephemeral stream systems recorded by the USGS on 1:24,000 scale topographic maps of the basin. An analysis of these maps indicates a total of 172 first-order streams and 22 first-order stream systems, 16 second-order stream systems, 5 third-order stream systems and 3 fourth-order stream systems within the Comanche Basin. The stream ordering system advocated by Strahler (1952) was used. This stream ordering system indicates not only size and scale, but also an approximate index of the amount of flow that can be produced by stream systems (Gregory and Walling, 1973). The larger streams, including Comanche, Sand, Difficulty and Brown creeks, and the larger ponds, impoundments, and potholes of the Comanche Basin are shown on Figure 5.2-1.

Maps indicate 399 miles of intermittent streams and 25 miles of perennial small streams in the Comanche Basin. The ratio of the total stream distance to the surface area of the basin is 1.84 miles/miles^2, which is low, indicating the relative aridity of the basin (Wilson, 1987). The intermittent streams carry water when runoff is heavy, usually during spring. During the cold season, precipitation falls as snow, which typically melts by early spring. The period of heaviest rainfall is also May and June (see also Section 7.3). Approximately one year in ten, heavy runoff causes minor flooding of some streams. Summer precipitation almost always occurs in showers and seldom contributes significant runoff to streams (Meshnick et al., 1972; Parker et al., 1980). The topographic maps indicate that a few streams are fed by springs as well.

USGS maps indicate that the 102 perennial small ponds and impoundments cover 0.49 square miles, and the 96 intermittent ponds and potholes, 1.31 square miles, for a total of 1.80 square miles, or 78 percent of the entire water surface area of the Comanche Basin. Six intermittent and four permanent ponds exceed 10 acres in surface area. These ten largest ponds, numbered 1 through 10 on Figure 5.2-1, measure 776 acres (67 percent of the total surface water area). The surface area of the Spidel Waterfowl Production Area, the largest pond shown, measures 629 acres and contributes 55 percent of the total surface area of the mapped water features.

Although the site is almost entirely within the Comanche Basin, sections of the western part of the collider ring are located just outside the Comanche Basin in the Lake Basin and the Painted Robe Creek watersheds (Figure 5.2-1). Ring construction will disturb Lost Creek and its tributaries in several places as they flow south westward toward Halfbreed Lake and several smaller unnamed ponds that are part of the Halfbreed Lake National Wildlife Refuge. The Painted Robe Creek watershed to the northwest will also be affected. Ring construction will disturb Gooseneck Creek and its tributaries, along with another unnamed creek and its tributaries toward Painted Robe Creek, which flows to the Musselshell River. All of these features are classified as intermittent streams on the USGS topographic maps, with streamflow patterns similar to those characteristic of the Comanche Basin. Impacts to the ephemeral streams at the margins of these other watersheds may be confined to the immediate site through appropriate mitigation measures (Wilson, 1987; Section 5.8.2.2).

5.2.2 Surface Water Quantity

The streams within the site typically carry runoff only in spring and early summer. The perennial and intermittent ponds, potholes, and small reservoirs expand and contract with water supply from season to season and year to year.

Aerial photographs were analyzed to estimate the basin surface water resources. Aerial photographs of the area are available for July 1957, June 1979, and May 1980. Analysis indicated that the combined surface areas of the ten largest lakes varied between 417 acres and 516 acres during those years and seasons (compared with the 778 acres designated on the 1:24,000-scale USGS topographic maps) (Table 5.2-1). Only the surface areas covered with water in the aerial photographs are reported in this analysis; variations indicate the tendency for ponds and reservoirs to dry up quickly in the dry summer months following spring replenishment with snowmelt and spring rains. The surface areas designated on the aerial photographs corresponded closely (<5 percent variation) with the surface areas of the depressions occupied by these water bodies identified on the USGS maps (Wilson, 1987).

5.2.3 Surface Water Quality

No published water quality data are available for the lakes and streams in the Comanche Basin. However, the geologic materials and soils in the adjacent lake basin to the west are so similar that water quality data recorded for Big Lake is probably similar (Wilson, 1987). Big Lake drains soils of the Lardell-McKenzie association. These soils consist of deep, nearly level, somewhat poorly drained to poorly drained clay loams and clays (Parker et al., 1980). The Comanche Basin is dominated by soils of the Vananda-McKenzie-Arvada associations, which consist of level to gently sloping deep clays to loams over clay in a dry (closed) basin (Meshnick et al., 1972).

The water quality data for Big Lake summarized in Table 5.2-2 indicates that surface water in the basin is a sodium sulfate type. Total NH_4 is relatively high, and both nitrogen and phosphorus levels are high enough to encourage plant growth. No data were available for dissolved oxygen. The water quality probably has some seasonal variation that cannot be identified with the data in Table 5.2-2, although the small range in water parameter values indicates that the water is homogeneous.

These conditions are consistent with the widespread occurrence of saline seeps in the Comanche Basin (Section 3.1.3). A number of factors present in the Comanche Basin and elsewhere in Montana aggravate the occurrence and spread of saline seep: the presence of soil, subsoil, and underlying geological formations that contain a nearly inexhaustible supply of water-soluble salts; a climate in which a large part of the annual precipitation occurs in spring before crops can utilize stored moisture effectively and before evapotranspiration is significant; a virtually impermeable material (shale or clay) beneath the soil profile that effectively impedes the downward movement of water, thus forming a "perched" or near-surface body of groundwater; and the development of a local groundwater flow system that allows saline groundwater to migrate from upland recharge areas toward nearby discharge (saline seep) areas (Thompson and Custer, 1976; Lewis et al., 1979; Miller et al., 1980).

To supplement the water quality data for Big Lake Basin, surface water samples were taken in the summer of 1987 from four small ponds and a stream in the Comanche Basin. These samples show pH ranging from 1270 mg/l to 8420 mg/l. The water quality data for the Comanche Basin indicates characteristics generally similar to those of Big Lake, although dissolved solids are not as high. Table 5.2-3 summarizes the available Comanche Basin surface water quality data from the Summer 1987 sampling.

5.2.4 Flood Areas and Frequencies

Because of the seasonal character of precipitation and runoff, the intermittent streams and small ponds are nearly always filled with water during spring and early summer but are frequently dry the rest of the year. In years with exceptionally heavy precipitation, the streams, potholes, and impoundments may flood small areas of adjacent farmland. Comanche Flat, the large depressional area in the middle of the basin, is flooded in wet years as well, although in most years this area dries up early enough in summer to be cultivated or used for grazing cattle (Wilson, 1987) (Figure 5.2-1).

The 1979-1980 aerial photographs were used to quantify the extent of flooding in Comanche Flat, since 1.6 times the normal precipitation was measured at Broadview in 1978 (22.19 inches compared with the 1951-1980 thirty-year annual average of 13.99 inches). This water drained to Comanche Flat and flooded an area in excess of the 526 acres that was still under water when the May 1980 aerial photographs were taken. Evaporation may take several years, as indicated by the 1978 precipitation and the 1980 aerial photographs, since 1977, 1979, and 1980 were relatively dry years. The flooded area was almost (67 percent) as large as the surface water features designated on the USGS topgraphic maps, indicating the presence of a large floodplain in the center of the basin (Wilson, 1987).

Table 5.2-2

Water Quality Data For Big Lake, Lake Basin, Montana

Water Quality Parameters	Units	Average	Range
Calcium, dissolved	mg/l	68	55-100
Chloride, dissolved	mg/l	414	380-480
Fluoride, dissolved	mg/l	0.4	None
Hardness	mg/l	2580	2300-3200
Hardness, N. Carb. L-EP	mg/l	2100	1900-2600
Iron, dissolved	ug/l	60	50-80
Magnesium, dissolved	mg/l	578	530-700
Manganese, dissolved	ug/l	140	10-660
Nitrogen, dissolved $NO_2 + NO_3 - N$	mg/l	<0.1	None
Nitrogen, total $NO_2 + NO_3 - N$	mg/l	<0.1	None
Nitrogen, total NH_4 as N	mg/l	0.30	0.01-0.42
Nitrogen, total Org. as N	mg/l	3.1	2.7-3.6
Nitrogen $NH_4 + 5$ g as N	mg/l	3.4	3.0-4.0
pH (laboratory)	Units	8.8	8.6-8.9
pH (field)	Units	9.0	8.8-9.2
Phosphorus, total (total - PO4)	mg/l	0.16	0.12-0.34
Phosphorus, total	mg/l	0.05	0.04-0.11
Potassium, dissolved	mg/l	18.8	18-19

Table 5.2-2 (Continued)

Water Quality Data For Big Lake, Lake Basin, Montana

Water Quality Parameters	Units	Average	Range
Silica, dissolved	mg/l	1.4	<1.2-2.4
Sodium, absorption ratio	--	20	18-22
Sodium, dissolved	mg/l	2340	2100-2900
Sodium, percent	%	66.6	65-67
Specific conductance (field)	umhos	11900	11200-13700
Specific conductance (lab)	umhos	11200	10600-13200
Sulfate	mg/l	6380	58000-80000

Range from 5 samples collected in December 1983

Table 5.2-3

Water Quality Data For Comanche Basin, Montana

Water Quality Parameters	Units	Average	Range
Temperature	°F	77	68-86
pH	Standard Units	8.5	8.0-9.2
Dissolved Oxygen	mg/1	10.7	9.9-13
Turbidity	NTu	15.7	1.8-46
Total Solids	mg/1	3934	1330-8730
Total Dissolved Solids	mg/1	3790	1270-8420
Total Alkalinity as $CaCO_3$	mg/1	390	190-689
Total Kjeldahl Nitrogen as N	mg/1	2.1	0.6-4.5
Ammonia Nitrogen as N	mg/1	0.6	0.4-0.7
Nitrate + Nitrite as N	mg/1	<0.05	None
Ortho-Phosphorus as P	mg/1	0.1	0.50-0.13
Bicarbonate Alkalinity as HCO_3	mg/1	431	193-808
Dissolved Metals			
Arsenic as As	mg/1	0.01	<0.005-0.012
Barium as Ba	mg/1	<0.1	None
Boron as B	mg/1	0.5	0.2-1.0
Cadmium as Cd	mg/1	<0.005	None
Chromium as Cr	mg/1	<0.02	None
Cobalt as Co	mg/1	<0.05	None
Copper as Cu	mg/1	<0.02	None

Table 5.2-3 (Continued)

Water Quality Data For Comanche Basin, Montana

Water Quality Parameters	Units	Average	Range
Iron as Fe	mg/l	0.35	.06-.81
Lead as Pb	mg/l	<0.02	None
Manganese as Mn	mg/l	0.31	.07-.83
Molybdenum as Mo	mg/l	<.05	None
Nickel as Ni	mg/l	<.02	None
Selenium as Se	mg/l	<.005	None
Vanadium as V	mg/l	<0.2	None
Zinc as Zn	mg/l	<.02	None

* Data collected on July 28, 1987

5.4 VEGETATION

The Comanch Basin site is characterized primarily by mid-grass prairie, with some wetland vegetation in lowland areas and with ponderosa pine cover on the rock outcroppings and broken drainage slopes outside the site's eastern perimeter. No threatened or endangered plant species are known or expected to occur in the vicinity (Heinze, 1987).

A significant portion of the area is cultivated for dryland farming or used for livestock grazing. There are no prime farmlands in the area (Robertson, 1987; BPA et al., 1979).

5.4.1 Significant Botanical Resources

The site lies in the Northern Great Plains physiographic province. The Soil Conservation Service (SCS) has identified five broad geographic zones in Montana to aid in describing the native vegetation and rangeland, including the Western Sedimentary Plains where the site is located. Vegetation in this zone consists primarily of grassland and shrub/grassland types, as well as some Conifer-Savannah vegetation. The specific botanical resource is dictated by soil, aspect, climate, elevation, and land uses (Ross and Hunter, 1976; BLM, 1983b; BLM, 1981).

5.4.1.1 Existing Vegetation Types

The Comanche Basin area itself is mixed prairie grassland, encompassing three climax vegetation types, according to the SCS classification system, which is based primarily on soil and climate (See Figure 5.4-1). These include the "Dense Clay-Clayey- Saline Upland Range Site Complex" in the low-lying and poorly drained center of the basin, the "Clayey and Shallow Clay Range Site Association" predominant on the western side of the basin and part of the eastern side, and "Silty Range Site" on the remaining ground (Ross and Hunter, 1976; BLM, 1983b). Table 5.4-1 lists the dominant climax vegetation species found in each of these areas, along with species that increase with grazing pressure, such as that in most parts of the basin not already cultivated.

This general characterization was further refined through an on-site inventory of the local botanical resource (Ross and Hunter, 1976). One preliminary inventory of the area revealed that the three grassland dominants are western wheatgrass, needleandthread, and blue grama. Other abundant grasses include Sandberg bluegrass, green needlegrass, bluebunch wheatgrass, and prairie junegrass. Threadleaf sedge and needleleaf sedge also are common, as are phloxes. Shrubs are codominant with grasses in much of the area. The most prevalent shrubs are the sagebrushes, with fringed sagewort most frequently encountered, and big sagebrush exerting a strong community influence when present. Plains pricklypear also is abundant in more heavily grazed areas. It was further found that "the only other distinctive rangeland community of significant extent is found in lowlands of the Comanche Basin having heavy and alkaline soils, and is dominated by greasewood and western wheatgrass" (DNRC, 1976; see also, DNRC, 1974b).

Other surveys have revealed two additional vegetation types of interest in the proposed project vicinity. One is the occasional occurrence in the basin lowlands, to a greater or lesser degree depending upon surface water conditions, of wetlands-type vegetation. It was noted by one investigator that "the wetland usually is dry and normally is dominated by western wheatgrass... The wetland occasionally holds standing water for several years... [After one such period, vegetation] was sparse in spring except for dense beds of algae (Tetraspora spp.) around the shoreline. Most of the wetland was dominated by narrow-leaved waterplantain (Alisma gramineum) during the growing season. Some areas supported stands of spikerush (Eleocharis spp.), hardstem bulrush (Scirpus acutus), and cattail (Typha spp.). The only submerged aquatic species noted was sago pondweed (Potamogeton pectinatus), commonly occurring in scattered beds" (Malcolm, 1982).

The other vegetation type of interest lies outside the eastern boundary of the proposed site, where there are shale and sandstone uplands which support scattered stands of ponderosa pine. These often occur along north-facing sandstone outcrops. Basal areas and mean tree heights are low, and growth is slow. The understory of these stands is often sparse. Rocky mountain juniper may be associated with ponderosa pine, especially on the poorer, droughty soils of the shaley breaks. Other common associates are skunkbush sumac, bluebunch wheatgrass, and many previously mentioned prairie species. Some stands resemble a more open savannah type, with scattered pinetrees and grasslands (DNRC, 1976; see also DNRC, 1974b).

Table 5.4-1

Climax Vegetation
(By Soil Unit)

Soil Units	Dominants in the Climax Vegetation	Plants that Increase with Grazing Pressure***
24. Forest-Grassland Complex (12-14" P.Z.)***	(On very shallow to deep soils with frigid temperature regimes. These soils have light brown, loamy surfaces and occur on rolling to hilly terrain.	
Forest: (50%)	Ponderosa pine Rocky Mountain juniper Little bluestem Bluebunch wheatgrass Sideoats grama Skunkbush sumac Western wheatgrass Native legumes	Needleandthread Western wheatgrass Prairie junegrass Snowberry Fringed sagewort Other weedy forbs Annuals
	(Rocky Mountain juniper will increase in areas where ponderosa pine has been removed by fire, logging, insects, or disease.)	
Grassland: (50%)	Little bluestem Needleandthread Western wheatgrass Green needlegrass Bluebunch wheatgrass Prairie sandree Big bluestem Native legumes Skunkbush sumac Yucca Prairie junegrass Blue grama	Needleandthread Blue grama Threadleaf sedge Prairie junegrass Sandberg bluegrass Big sagebrush Fringed sagewort Hairy goldenaster Other weedy forbs Broom snakeweed Annuals

Table 5.4-1 Continued

Climax Vegetation
(By Soil Unit)

Soil Units	Dominants in the Climax Vegetation	Plants that Increase with Grazing Pressure**
27. Silty Range Site (10-14" P.Z.)	Bluebunch wheatgrass Western and thickspike wheatgrass Needle and thread Green needlegrass Basin wildrye Threadleaf sedge Prairie junegrass Native legumes Big sagebrush Skunkbush sumac Common chokecherry Blue grama	Blue grama Needleandthread Sandburg bluegrass Threadleaf sedge Prairie junegrass Big sagebrush Western snowberry Rabbitbrush Broom snakeweed Fringed sagewort Hairy goldenaster Western yarrow Pussytoes Other weedy forbs Annuals
31. Clayey and Shallow Clay Range Site Association (10-14" P.Z.)	Western and thickspike wheatgrass Bluebunch wheatgrass Green needlegrass Big sagebrush Prairie junegrass Plains reedgrass Prairie sandreed (Growing on fractured shale outcrops) Milkvetch	Big sagebrush Blue grama Prairie junegrass Needle and thread Sandberg bluegrass Rabbitbrush Broom snakeweed Eriogonum Annuals White pointloco Milkvetch Onion Other weedy forbs

Table 5.4-1 Continued

Climax Vegetation
(By Soil Unit)

Soil Units	Dominants in the Climax Vegetation	Plants that Increase with Grazing Pressure***
34. Dense Clay-Clayey-Saline Upland Range Site Complex		
(10-14" P.Z.)		
Dense Clay:	Western and thickspike wheatgrass Green needlegrass Inland saltgrass Big sagebrush Nuttall saltbrush Greasewood Prairie junegrass Sandberg bluegrass	Big sagebrush Rabbitbrush Prairie junegrass Sandberg bluegrass Inland saltgrass Onion Other weedy forbs Annuals
Clayey:	Same as Site No. 31	
Saline Upland:	Alkali sacaton Western and thickspike wheatgrass Greasewood Nuttall saltbrush Basin wildrye Inlands saltgrass Big sagebrush Bottlebrush squirreltail	Greasewood Big sagebrush Inland saltgrass Bottlebrush squirreltail Plains pricklypear Sandberg bluegrass

Table 5.4-1 Continued

Climax Vegetation
(By Soil Unit)

Soil Units	Dominants in the Climax Vegetation	Plants that Increase with Grazing Pressure**
36. Forest-Grassland (12-14" P.Z.)	(On very shallow to deep soils with a frigid temperature regime. These soils have light brown, loamy surfaces and occur on all rolling to steep terrain).	
Forest: (50%)	Ponderosa pine Rocky Mountain juniper Bluebunch wheatgrass Western wheatgrass Skunkbush sumac Snowberry Needleandthread	Needleandthread Western wheatgrass Prairie junegrass Snowberry Rose Fringed sagewort Other weedy forbs
Grassland: (50%)	Bluebunch wheatgrass Needleandthread Western and thickspike wheatgrass Green needlegrass Big sagebrush Prairie sandreed Native legumes Prairie junegrass	Needleandthread Western and thickspike wheatgrass Blue grama Sandberg bluegrass Big sagebrush Broom snakeweed Rabbitbrush Fringed sagewort Hairy goldenaster Other weedy forbs Annuals

*Listed in approximate order of dominance
**Based primarily on response to grazing pressure by cattle
***P.Z. = Precipitation Zone

Source: Ross, R.L. and H.E. Hunter, 1976.
Soil Conservation Service (SCS), Bozeman, MT.
Climax Vegetation of Montana, Based on Soils and Climate

5.4.1.2 Agricultural Resources

Most of the land in the basin is or has been cultivated for dryland farming, the main crops being winter wheat and barley (DNRC, 1974b Map; USDA Committee for Rural Development, 1973; Meshnick, et al., 1972). There are no prime farmlands in the area (Robertson, 1987; BPA et al., 1979). Land productivity varies considerably due to the complexity in depth and aspect of the soils. Recent herbage yields from several typical sites in this type are as follows:

In the 10-14 inch precipitation zone, silty, sandy and clayey sites produce between 700 and 1400 pounds/acre annually;

Strongly saline sites produce an estimated yield of 300 pounds/acre in normal rainfall years, with very little herbage production evident during low precipitation periods (BPA et al., 1979).

Extensive irrigation to upgrade this land is not generally considered feasible (BOR, 1972). Only one local farmer is known to irrigate portions of his land.

Much of the remainder of the Comanche Basin site serves as rangeland (USDA Committee for Rural Development, 1973). Range production may vary widely, with average production for the area estimated at 3.0 to 4.0 acres/Animal Unit Month (a/AUM) (DNRC, 1974b, see also BPA et al., 1979).

The isolated ponderosa pine stands in the site vicinity are not sufficiently accessible, extensive or sizeable to justify commercial exploitation (DNRC, 1974b; BPA et al., 1979).

5.4.2 Threatened or Endangered Species

No threatened or endangered plant species are known or anticipated at the proposed site (Heinze, 1987). The only two sensitive species under consideration by the BLM for this classification that may occur in the general region are a buckwheat (Eriogonum lagopus) and a watercress (Rorippa calycina). Neither has been located in the region to date (BLM, 1983b; BLM, 1981).

5.5 AIR QUALITY

5.5.1 Existing Air Quality and Air Quality Limitations

Sources of air pollutants in the site area include agricultural activities in the vicinity, which generate particulates; and petroluem refineries and coal-fired power plants in Billings which emit sulfur dioxide, nitrogen dioxide, and particulates. The sources in Billings are approximately 15 miles southeast of the site. Dispersion modeling conducted by the State of Montana Air Quality Bureau (AQB) for the Billings area indicates that no significant concentrations of any regulated pollutant should occur at that distance from Billings (Sternberg, 1983). Moreover, the site is upwind of the Billings area, and consequently winds blow infrequently from the direction of Billings. (Wind rose data and a detailed summary of meteorological conditions affecting dispersion characteristics of the region are contained in Section 7.3).

There has been no monitoring of air pollutants in the Acton- Broadview area. The AQB has monitored total suspended particulates (TSP) at several background locations in Eastern Montana and believes that these measured concentrations are representative of the site (Robbins, 1987). The TSP data from the AQB's background sites indicate that annual TSP concentrations in rural, agricultural areas of eastern Montana generally average from 15 to 35 micrograms per cubic meter (ug/m3) in areas devoted to grain cultivation and 8 to 20 ug/m3 in areas used for pasture and grazing. The highest 24-hour average TSP concentrations that can be expected are 50 to 150 ug/m3 in cultivated areas and 25 to 35 ug/m3 in pasture and grazing areas (Raisch, 1982).

An air quality permit will be necessary for the construction of the project. The primary regulatory concern would involve total suspended particulates generated by construction activities, which may be mitigated by a number of dust suppression measures.

The federal and Montana air quality standards are listed in Table 5.5-1. The Montana ambient standards generally are somewhat more restrictive than the federal standards. The attainment status of the area, as defined by the 1977 Clean Air Act Amendments, is "unclassified" for all pollutants. The area is classified as Class II under the Prevention of Significant Deterioration (PSD) Regulations.

Table 5.5-1

Montana and National Air Quality Standards

Pollutant	Montana Standard	Federal Primary Standard	Federal Secondary Standard
Total Suspended Particulates	75 ug/m3 annual average 200 ug/m3 24-hour average	75 ug/m3 annual geometric mean 260 ug/m3 24-hour average*	60 ug/m3 annual geometric mean 150 ug/m3 24-hour average*
Sulfur Dioxide	0.02 ppm annual average 0.10 ppm 24-hour average* 0.50 ppm 1-hour average**	0.03 ppm annual average 0.14 ppm 24-hour average*	0.5 ppm 3-hour average*
Carbon Monoxide	9 ppm 8-hour average* 23 ppm hourly average*	9 ppm 8-hour average* 35 ppm 1-hour average*	9 ppm 8-hour average
Nitrogen Dioxide	0.05 ppm annual average 0.30 ppm 1-hour average*	0.05 ppm annual average	0.05 ppm annual average
Ozone	0.10 hourly average*	0.12 ppm 1-hour average*	0.12 ppm 1-hour average*
Lead	1.5 ug/m3 90-day average	1.5 ug/m3 calendar quarter average	None
Foliar Fluoride	20 ug/g monthly average	None	None
Hydrogen Sulfide	0.05 ppm hourly average*	None	None
Dustfall	10 gm/m2 30-day average	None	None
Visibility	Particle scattering coefficient of 3 X 10-5 per meter annual average***	None	None

* Not to be exceeded more than once per year
ug/m3 Micrograms pollutant per cubic meter of sampled air
Ppm Parts pollutant per million parts of sampled air
** Not to be exceeded more than 18 times per year
*** Applies to PSD Class I areas

5.6 BACKGROUND RADIATION

The sedimentary rocks underlying the Comanche Basin generally contain very small amounts of radioactive elements that contribute to the low background radiation observed. There are two geologic formations under the Comanche Basin that may contain slightly elevated concentrations of uranium and other radioactive elements. These formations are the Bearpaw shale, which locally contains deposits of bentonite, and the Virgelle sandstone, a favorable environment for "Texas" roll-type deposits that may contain enriched uranium concentrations (Warchola and Stockton, 1982).

As part of the National Uranium Resource Evaluation (NURE), an airborne gamma ray and total magnetic field survey of the Comanche Basin and the surrounding area was made in 1978. Results of these analyses are presented in Tables 5.6-1 and 5.6-2. The NURE airborne study evaluated the average radiation in the area as a function of geologic unit. These data indicate average radiation levels due to thallium-208 to be 35 to 40 counts per second for the formations present under the Comanche Basin. For bismuth-214, the average radiation values were 12 to 17 counts per second, and for potassium-40, the average radiation was 125 to 140 counts per second.

The NURE airborne study was supplemented by geochemical sampling of groundwater and stream sediments. The analyses of groundwater taken from the Comanche Basin indicated uranium concentrations of 4 to 16 parts per billion (ppb). The stream water samples taken in the area had uranium concentrations ranging from 10 to 65 ppb. The stream sediment samples taken in the Comanche Basin indicated uranium concentrations of 2 to 4 parts per million (ppm) (Whitlock and Van Eeckhout, 1980).

5.7 HISTORICAL AND ARCHAEOLOGICAL RESOURCES

The Montana State Historic Preservation Office (SHPO) has identified 85 prehistoric and historic sites within the townships traversed or circumscribed by the proposed project (Table 5.7-1). Most of these sites were recorded in the 1960's and early 1970's by members of the Billings Archaeological Society, when the standards for recordation were not as exacting as they are today. Only one of the recorded sites is listed on the National Register of Historic Places. Evaluation of many of the sites' significance and eligibility for registration would require further field visitation and study (Stanfill, 1987a).

The site listed on the National Register of Historic Places is a log hotel which once was the Antelope Stage stop on the historic stage route from Billings to Lavina (Figure 5.7-1). It is located in Area C, the campus expansion area. Any adverse impacts to the structure, therefore, may be avoided by appropriate site design at the campus. The structure may, in fact, be incorporated as a positive element in the campus design. The potential impacts to this structure and the other prehistoric and historic sites in the area are discussed in Section 5.8.9.

Since the area also has not been extensively or systematically surveyed to date, other sites may exist. The SHPO, however, believes that the recorded sites are probably representative of the range of site types that occur there (Stanfill, 1987b). Most of the cultural resources at the recorded sites are relatively common to the general region.

It should be pointed out that a significant percentage of the land surface at the proposed site has been disturbed for cultivation and grazing, as well as other land uses. This may well have resulted in the destruction of other cultural resource sites in the area. The surface water characteristics of the area, such as periods of significant runoff and ponding, likewise may have resulted in a higher than usual rate of site destruction for the locale.

5.7.1 Prehistoric Resources

There is evidence of human occupation of the region through all prehistory, encompassing three general culture periods: Paleo- Indian (10,000-5,500 B.C.); Plains Archaic (5,500 B.C.-A.D. 500); and Late Prehistoric (A.D. 500-1800). During all three periods, life on the Northwestern Plains involved hunting and gathering. Because of this, the people lived in small groups, had no permanent settlements, and possessed only limited tools made of stone, wood, or bone. Most of the prehistoric sites, therefore, are small, containing limited evidence of brief inhabitation or use (BLM, 1981; Fredlund, 1981; Ruebelmann, 1983).

Prehistoric sites in the area may be classified according to four functional types: habitation, procurement, industrial and ritual. Habitation sites, which evidence everyday domestic activities, include camp debris scatters, hearths, cairns and tipi rings. Procurement sites, associated with hunting and gathering subsistence activities, may include buffalo jumps, traps, pounds and related processing areas. Industrial sites would include quarries and workshops made up of scatters of lithic waste debris, hammerstones, rough or damaged tools and chunks of workable fine-grained rocks. Ritual sites in the region may consist of petroglyphs, pictographs, burials, medicine wheels, and rock or wooden structures for vision quests or other purposes (Ruebelmann, 1983).

The U.S. Bureau of Land Management has compiled a list of site types found on BLM lands in the region, broken down by cultural period and presented in Table 5.7-2. Lithic sites comprise the majority of prehistoric sites in the region, followed by tipi rings, hearths and fire-cracked rock, and rock art (BLM, 1983b).

The distribution of these prehistoric sites in the region varies according to environmental zones and topographic features. Sites average one or two per section of grassland or prairie zone and two or three per pine timbered zone (BLM, 1983b). Sites in all environmental zones tend to be associated with topographic features, particularly uplands areas, areas within 1.5 mile of watercourses, and dessicated topography (John Taylor, 1987). The older the site the more rare it tends to be, due to the greater likelihood of destruction by erosion and other elements. Comparatively recent sites, therefore, are the most common in the area (BLM, 1981).

The types of prehistoric sites identified by SHPO for the project vicinity include: lithic scatters, tipi rings, rock alignments, cribbed log structures, rock shelters, vision quest sites, petroglyphs and pictographs. Lithic scatters, followed by tipi rings, are the most prevalent type of site, with only a few instances of the other cultural site types. As might be expected, prehistoric site density is lowest in the central part of the basin, increasing toward the perimeter with elevation or environmental and topographical complexity (Stanfill, 1987a).

The nearest area of known archaeological significance is the Hoskins Basin Archaeological District, outside the northeast perimeter of the Comanche Basin site [T3N, R25E, Secs 5,7,8,17; T4N, R25E, Sec 31]. The District contains five sites with cribbed log structures, a rare conical timber lodge or wickiup, a vision quest structure, lithic scatter with component hearths, and bone debris. Hoskins Basin was determined an Archaeological District by the Fish and Game Commission in 1975, and now is listed in the National Register of Historic Places (Fredlund, 1981; BLM, 1983b; BLM, 1983a).

5.8 PRELIMINARY ENVIRONMENTAL EVALUATION

The purpose of the preliminary environmental evaluation is to identify environmental impacts that would require special attention or could limit the use of the Comanche Basin site. The evaluation is based on results of initial consultation with affected federal, state, and local resource agencies, field reconnaissance, analysis of available data and information and interpretation of aerial photography. Assessment focused on major surface disturbances and socioeconomic effects associated with the construction and operation of the SSC at the proposed site.

Based on the proposed facility arrangement, major surface disturbances include:

- Facilities. The campus and injector areas (A, B, and C) will require a total of 3500 acres. A large percentage of this area is reserved for future expansion, and so will not be disturbed unless and until the campus is expanded in the future. The collider arcs (area D) will be built mostly by tunneling. Approximately 3.5 miles of the arcs will be built by cut-and-cover methods, disturbing the surface. The intermediate access (E) and service areas (F) on the collider arcs will result in the disturbance of approximately 0.9 and 5.7 acres each, respectively, for a total disturbed surface area of 6 and 34 acres. The abort/external beam access areas (J) will each require 40 acres, for a total of 240 acres of disturbed surface. Approximately 2.1 to 2.6 million cubic yards of "spoil" material will be excavated from the tunnels. All of this material will be used to upgrade the road system and provide fill material in the campus area.

- Road Network. Access to the SSC facilities during construction and operation will be provided by improvement of existing roads and construction of new roads. Major improvements are planned for Montana Highway 3, the Acton to Campus road, and the Acton to F5 road. All road improvements will include widening and building up of the existing grade and paving of the road surface. About 90 miles of existing road will be upgraded, while about 8 miles of new road will be built.

- Pipelines. Water and natural gas will be supplied to the SSC by new pipelines coming into the area from the outside. The distribution of water and natural gas to the SSC facilities will require the construction of distribution pipelines within the Comanche Basin. These distribution pipelines will be placed adjacent to the access roads to avoid additional surface disturbances.

- Powerlines. Two new powerlines will be built to provide electrical service to the SSC facilities. One powerline will run along existing electrical corridors from the Broadview substation to the campus area. A second powerline will run from the Broadview substation to the F5 area. Further distribution of electricity from these two locations will be through the tunnel, so there will be no additional surface disturbances due to powerlines.

Also included in the evaluation were the socioeconomic effects of the construction and operation of the SSC. The SSC will attract approximately 10,000 people to the area. Most of these people will likely choose to live in Billings, because it is nearby and because of the amenities available there. Billings already has in place surplus capacity to serve the new population. In addition, the city has expressed its willingness to supply whatever additional services are required to support the SSC.

Several other aspects of the project were considered but not included in the preliminary environmental evaluation, as follows:

- Pipelines Off-Site. Natural gas will be supplied by a new pipeline from the northwest of the Comanche Basin. Potable water and industrial water will be supplied by a new water pipeline from Billings. The precise route of these pipelines, outside the Comanche Basin site, has not yet been determined.

- Waste Disposal. Specific plans for the transport and disposal of waste materials have not been developed. Sewage generated after the SSC is in operation will be treated at the sewage treatment plant to be constructed near the campus area. Sewage disposal for intermediate access and service areas will be effected by septic tanks or portable chemical facilities. The solid waste generated by the SSC will be carried offsite to the existing Billings disposal facility. The hazardous waste produced by the SSC also will be transported to a certified hazardous waste disposal facility in Colorado or Utah.

- Decommissioning. DOE has not yet formulated specific plans for the decommissioning of the SSC (Ref. DOE answer to Question No. 644, 7/17/87). It is expected, however, that decommissioning impacts can be minimized through cooperative advance planning, and by taking advantage of the ancillary regional economic development and continued economic diversification fostered during the SSC's operational years.

Based on current information, the state of Montana does not expect any of the above considerations to cause significant impacts that could limit the use of the site.

5.8.1 Topographical, Geological, and Soil Resources

5.8.1.1 Topographical Resources

The proposed project is unlikely to have any major impact on topographic resources of the area. Some site leveling will be required for construction and some final landscaping. The campus area will constitute most of these impacts, followed by the west cluster, with the rest at isolated service, access, and other small facilities around the collider ring. Some of the proposed access road improvements and construction, as well as sewage and other wastewater ponds, also will involve small-scale topographic impacts.

Most of the collider ring itself will be constructed by tunneling, with no topographic impacts. The ring will be constructed by the cut-and-fill method at four locations: One cut approximately 2 miles long and 300 feet wide at a stretch between F2 and E3 running southwest of Acton; another cut from E5 to K4 in the far cluster, approximately 1.5 miles long, and about 500 feet wide in the middle but tapering to 200 feet wide at each end; a cut approximately 500 feet long and 200 feet wide at the Gooseneck Creek drainage near E7; and a cut approximately 200 feet by 200 feet between the railroad tracks and Montana Highway 3 at the northern arc of the ring. These cut-and-fill lands will be graded to approximate their original contour. At the two larger areas, the topography will be smoothed out somewhat along the path of the ring to provide adequate cover for the tunnel. The most significant impact will be removal of approximately 150 feet of hilltop between cut E5 and K4. The geomorphology of all drainages intersected by cut-and-fill construction, such as the Gooseneck Creek drainage, will be reestablished as nearly as possible in terms of channel width and gradient of floor.

5.8.1.2 Geological Resources

Geological resources at the site will not be significantly impacted by the project. Specifically, tunneling for collider ring construction should not result in any surface subsidence, given the depth and geological characteristics of the tunneling zone. Nor will there be any likely subsidence at areas of cut-and-fill construction, due to the requirement for controlled compaction of the replaced excavation material.

5.8.1.3 Soil Resources

Soil resources will be impacted at all areas of surface disturbance. According to the Soil Conservation Service, there are no prime farmlands at the site (Robertson, 1987). Typically there is only one relatively thin zone of topsoil.

The reclamation plan calls for removal and stockpiling of all topsoil from disturbed areas to be used to reclaim areas exposed after construction of surface facilities. If this topsoil resource is inadequate in any given area, soil from other sources must be procured and applied. To reclaim areas of Bearpaw shale, for example, it will be necessary to cover those areas with a sandy loam material, which probably will be available from construction elsewhere within the site. Once applied, the topsoil must be stabilized through revegetation to minimize erosion.

Impacts on topsoil resources at the site, therefore, will be temporary except where permanent facilities stand. Construction plans and schedules will adequately mitigate the interim erosion and loss of soil resources in the course of construction, both minimizing and localizing potential impacts. Montana's past research and experience in the reclamation of large-scale surface mined lands will ensure that state-of-the-art proven reclamation techniques are utilized to minimize impacts on soil, land, and vegetation resources during SSC construction.

5.8.2 Water Resources

Potential impacts of the project on the existing surface water and groundwater regimes at the site are expected to be localized and transient. From the standpoint of residents, the impacts are positive in that more abundant, better quality city water will be available for local use as a result of the project.

Surface water and groundwater resources in the Comanche Basin do not appear to intermix (Odell, 1987). The land surface generally is underlain, at relatively shallow depths, by layers of impermeable subsoil or rock, causing any water which does soak into the surface to move laterally. At certain outcrop areas, this may occur as saline seep. Surface runoff may stand in the basin for long periods of time until evaporated. At the same time, the groundwater aquifers are largely recharged from outside the basin. Apart from several minor springs and local wells groundwater generally does not appear at the surface (Wilson, 1987).

Surface water drainage may be altered in areas where construction disturbance cuts these impermeable subsurface layers, and surface water and groundwater regimes may intermix unless impermeable layers are re-established. The most negative potential effect of altered surface drainage is that saline seep may occur in new locations as water percolates to lower impermeable zones prior to lateral movement. It should be noted that even if this occurs, the impact will be highly localized and relatively insignificant, since the amount of water involved is only a portion of the total precipitation, which in turn represents a small percentage of the land base in the watershed (Id.).

5.8.2.1 Groundwater Resources

Groundwater quantity at the site may be affected by the proposed project, primarily by construction in the immediate vicinity of existing wells. Such effects will be mitigated, however, even resulting in improved water supplies to some affected landowners.

Construction of the collider ring, both tunneling and cut-and-fill, will have the most impact on groundwater resources. Approximately 18 miles of this construction will penetrate the two primary aquifers in the area, and roughly another 4 miles will penetrate pervious fault zones which may carry additional water. A requirement for construction through these areas, therefore, will be temporary dewatering. This will entail pumping water from the tunnel or pit areas until the ring liner is in place and construction moves on.

Dewatering will draw down or even interrupt groundwater supplies to wells within approximately 100 feet of the construction, possibly requiring that potable water be hauled to and stored for landowners. Adequate stockwater may be provided by the dewatering discharge itself. The local groundwater regime will probably return to its prior condition once construction in the vicinity is ended (Odell, 1987). There is a remote possibility that the groundwater supply to a given well may be affected by the ring itself blocking off part of the seam feeding that well. This may be mitigated, if and where it occurs, by providing an alternative well for landowners in unaffected areas or by providing them with hook-ups to the city water system planned to support the SSC facility.

Some existing wells will also be taken out of service intentionally, sealed and abandoned. These permanent impacts will be mitigated by providing alternative wells or city water hook-ups.

Groundwater quality in the area is not expected to be adversely affected by construction or operation of the facility, provided materials and water discharges associated with such activities are properly handled, as discussed below. Underground construction will not contaminate groundwater, and DOE has indicated that project operation poses no problems with respect to irradiated groundwater.

5.8.2.2 Surface Water Resources

Virtually all impacts on the surface water system will be confined to the Comanche Basin. The western part of the proposed collider ring route, however, involves cut-and-fill operations which will impact two additional watersheds. One is the Lake Basin, another internally drained basin to the southwest, and the other is the Painted Robe Creek watershed to the northwest, which drains to the Musselshell River. All of these features are classified as intermittent streams (USGS, 1:24,000 quad maps), with streamflow patterns similar to those of the Comanche Basin. Impacts to these other watersheds, therefore, may be confined to the immediate site through appropriate mitigation measures, as discussed in connection with similar Comanche Basin impacts (Wilson, 1987).

None of the larger named intermittent streams within the Comanche Basin watershed will be impacted, except for a tributary of Difficulty Creek, which will be affected by the large cut-and-fill operation along the southern arc. Likewise, none of the 10 largest ponds, identified in Section 5.2.1 as representing approximately two-thirds of the surface area of the basin's water resource, will be impacted. The only surface water features potentially affected by surface disturbance, therefore, are minor intermittent or ephemeral drainages and possibly some very small ponds or potholes.

Refinement of site design and construction plans, following further study of the area, may ensure that impacts on any surface water drainages are adequately mitigated by design and construction constraints, diversionary facilities, minimum grading requirements, runoff controls, or other appropriate measures to minimize and contain any impacts.

Similar protection will be provided for areas of permanent or intermittent surface water bodies. Given their likely occurrence in the basin, a survey of all potentially affected lands which may be classified as "wetlands" will be conducted, to avoid or properly mitigate any impacts to those areas (Section 5.2.1). Although the proposed site is believed to avoid any areas potentially classifiable as floodplains (Section 5.2.4), affected lands also will be surveyed for this possibility. Following the survey, a floodplain/wetlands assessment will be performed in conformance with DOE regulations (10 CFR 1022.12). This will ensure that all associated environmental and other values are properly considered and adequately protected.

There may actually be a small net increase in the quantity of surface water in the Comanche Basin. The existing surface water resource in the area consists almost entirely of runoff from snowmelt and rainfall within the basin, with minimal contributions from several springs. During construction, approximately 22 miles of the collider ring zone will be dewatered, pumping amounts of groundwater into temporary settlement ponds situated about every 5 miles along the affected area. Water from these ponds could be utilized locally on a temporary basis for agricultural purposes, with no anticipated negative impacts of any significance.

The permanent facilities also will contribute to the basin's surface water supply. It has been proposed that project potable and industrial cooling water demands be met with water from the Billings water system, with wastewater treated and discharged within the basin. For sewage disposal, this will consist of two lagoons, totaling 50-100 acres and situated within 1 mile of the campus area, to be used for evaporation of water discharged from an on-site sewage treatment plant. For industrial cooling water, a number of cooling towers will be situated around the collider ring at which there will be some water loss through evaporation and blowdown. Blowdown will be treated to appropriate water quality standards for discharge at low rates into small on-site evaporation ponds or directly into local drainage systems.

Therefore, no discharge water will be contributed to the existing surface water regime until it is properly treated and unless the amount is small enough to have no significant impacts.

A final important hydrologic consideration of the proposed project is the disposal of excavation material from tunneling and other construction operations. Although a substantial amount of excavation material will be produced (estimated at 2.1-2.6 million cubic yards), all of this material can and will be used in preparing the campus area and in building and improving the project access road network. Most of this excavation material will consist of sandstone, claystone, and siltstone which will not impact water quality. Some of the material, however, will consist of Bearpaw shale, which has saline and other chemical properties and must therefore be replaced in areas of like material.

All potential impacts on surface water and groundwater quality and quantity will be examined in the course of securing all necessary permits and licenses for the project; however, it is unlikely that the proposed project will have any major impacts on the local hydrologic regime.

5.8.3 Ecological Resources

5.8.3.1 Botanical Resources

Impacts on the botanical resources will be confined to areas of surface disturbance. Within those limited areas, impacts to vegetation will be substantial in the course of construction but will be largely mitigated through subsequent reclamation. Natural and agricultural vegetation will be permanently lost only on the relatively small percentage of land occupied by permanent surface facilities.

The vast majority of native plant species at the Comanche Basin are common to much of eastern Montana (Ross and Hunter, 1976). The sole exception is wetlands-type vegetation, the extent of which is not known but which will receive adequate protection through the required wetlands assessment outlined in Section 5.8.2. No threatened or endangered plant species are known or expected to occur in the project vicinity; however, field investigation will be conducted to ensure that no such species exist in affected areas, and that impacts on any such species found will be adequately mitigated.

All disturbed areas of natural vegetation, other than those occupied by permanent facilities, will be reclaimed and revegetated. Every major component of the native flora is available in seed, so that each area can be reclaimed to its approximate original condition. The necessary materials and expertise for such restoration have been developed already for surface mine reclamation at many other similar sites in southern Montana. Growing conditions for successful revegetation at the Comanche Basin site also are considered excellent. Although the area does not receive substantial annual precipitation, much of the precipitation it does receive is concentrated during the most critical part of the local growing season. No special efforts, therefore, will be necessary to ensure successful revegetation (Hines, 1987).

It should be remembered that the site is not a pristine area. Most of the affected land at the site is or has been subjected to cultivation or grazing. Areas of agricultural land use disturbed by project construction also will be restored by appropriate cropland revegetation.

5.8.3.2 **Wildlife Resources**

Construction of the project is not expected to have any significant, long-term impacts on the wildlife resources of the area. The most significant long-term impact on wildlife will be increased contact with people, as access to the area is improved and the human population increases. Wildlife will tend to avoid the few concentrated areas of human activity; however, increased roadkills and hunting pressure will occur throughout the project vicinity. Populations of local wildlife in most years are sufficiently abundant to sustain any such losses. (Id.)

The most significant short-term impact on wildlife will be the loss of some habitat from construction operations and associated noise and commotion. This is expected to cause only minor dislocation in most areas, with wildlife quickly reestablishing themselves elsewhere in the vicinity, and later frequenting reclaimed land (Hoem, 1987).

The proposed site does not support, and is not expected to support, any populations of threatened or endangered wildlife species (Eustace, 1987; Hoem, 1987). While individual bald eagles and peregrine falcons have been observed in the vicinity on rare occasions, their presence is believed to be incident to migration (Fries, 1987a). The likelihood of impacts on these species, therefore, is very small, and would be limited in any event to increased human activity. There is ample alternative habitat suitable for stopovers in the surrounding region. Affected lands at the proposed site will be surveyed to ensure that no threatened or endangered species will be impacted, or that appropriate mitigation measures will be undertaken.

The only wildlife habitat of any particular significance at the Comanche Basin site are the wetlands areas, although their significance varies from year to year with the extent of the available water resource. As previously noted, these areas may attract upwards of 100,000 waterfowl for breeding and stopover purposes during a wet year, or only a few hundred of waterfowl during a dry year. The most significant water body in the basin, constituting approximately 55 percent of the surface area of the basin's surface water resource, is the Spidel Waterfowl Production Area (WPA) administered by the U.S. Fish and Wildlife Service. In the past six or seven years, it has been completely dry at least one year, and so full for two others that it was a foot and a half deep over the county road that crosses it (Fries, 1987b).

Because of their largely intermittent or ephemeral nature, it is difficult to define the location or scope of these potential wetlands, and therefore the likely impacted areas. The collider ring actually will tunnel directly underneath the Spidel WPA, without any anticipated surface effects due to the required tunnel depth. None of the other large water bodies is expected to be affected. Survey, assessment, and protection of any potentially affected wetlands is discussed in Section 5.8.2. It may be possible, moreover, that the temporary disturbance or even the permanent loss of any existing wetland habitat can be easily mitigated. Affected areas could be restored or even enhanced following any construction disturbance, primarily by deepening, and equivalent wetland habitat could be created elsewhere in the basin if an existing site were eliminated.

There is one further consideration of concern for waterfowl, and that is the proximity of powerlines to their wetland habitat. The Comanche Basin already is crossed by a number of high voltage lines which pose a potential threat to waterfowl using the basin. New powerlines should be routed to minimize impacts near potential wetland habitat. For this reason, the two new high voltage lines should follow existing power corridors, so that no new plane of obstruction to waterfowl flight is created, or sited at a safe distance from identified wetlands areas. All lower voltage distribution lines will be placed underground in the collider tunnel. Any new wetland habitat created should be situated at a safe distance from new and existing high voltage lines.

As discussed in relation to vegetation impacts, a relatively small amount of other wildlife habitat, consisting primarily of grasslands and shrub/grasslands, will be disturbed during tunneling and facilities construction. This habitat will be either replaced by permanent facilities, or will be reclaimed to its approximate original condition, suitable again for wildlife habitat. None of these affected areas constitutes critical wildlife habitat. Disturbed lands also represent only a small percentage of similar habitat available throughout the region.

5.8.4 Land Resources

The existing land use of virtually all affected areas is either dryland farming or livestock grazing. While the Comanche Basin site is a productive area for such uses, the land resource is not unique. Only a small percentage of the basin's land will be affected.

Agricultural lands disturbed during construction will be returned to their prior use, except in those areas conveyed in fee simple to the federal government (See Section 2.1.6). Any such areas not occupied by above ground facilities could be leased back to the landowner for agricultural purposes at the discretion of the DOE.

5.8.5 Socioeconomics

The potential socioeconomic impacts associated with a project of this magnitude are a function of the size and characteristics of the in-migrating population associated with the project. The "new" population will create demands on public, quasi-public, and private services and facilities, including:

- Water and sewer facilities and services,
- Educational services and facilities,
- Police and fire services and facilities,
- Streets and roads,
- Housing,
- Utilities (gas, electricity, telephone),
- Retail services (motels, restaurants, shopping, etc.)
- Social services,
- Medical facilities and services

The types of impacts and the levels of impact will be a function of several factors, including:

- Size and timing of population in-migration (number of people, duration of stay, "peak" population levels)

- Characteristics of the new population (ages, family size, income, educational and skill levels)

- Work forces associated with the construction and operation periods will create different types of demands due to differences in skills, amount of time at the site, family accompaniment, commuting patterns, etc.

A preliminary analysis of the potential impacts associated with the construction and operation of the SSC facility in Montana shows two main geographical areas of potential impact:

- The City of Billings
- The immediate area around the project site, which includes the community of Broadview

The level of impact will be a function of local labor force participation rates, the characteristics of the in-migrating work force and the geographic distribution of the in-migrants. Based upon the distribution patterns of non-local construction workers and operations workers on major projects in the west (Colstrip, Montana; Beulah, North Dakota; and Wheatland, Wyoming, for example), almost all of the labor force will locate in Billings. This is due to the amenities offered and proximity of the city to the project area (approximately 20 miles). At this time, it does not appear that Billings will receive any significant negative impact from the project, for the following reasons:

- The city has, in place, surplus capacity in the physical infra-structure necessary to serve the new population. This is true in housing, water and sewer treatment, distribution and collection fire and safety facilities, utilities, medical facilities, and education facilities. While additional staffing and some equipment might be required, these are not major expense items. In addition, the city has expressed its willingness to provide whatever services are necessary to support the project-related population.

- Forecasting models are available and have been used in the area to estimate population inflows, facilities and services impact, and revenue (tax) flows. By developing reasonable forecasts and monitoring project activities, it is possible to plan both for growth and decommissioning needs of the project well in advance, in order to minimize any potential negative impacts.

- Data bases on Billings and the region are available that can aid forecasting, in terms of timing and levels of accuracy.

Because Broadview is small and the area between Billings and Broadview is sparsely populated, some impacts can be expected in the immediate project area. Even low levels of population in- migration will create demands that exceed existing capacities in all of the categories described above. In addition, improvements to the highway linking the project to Billings will have to be made and additional transportation services offered. However, with proper planning (using the forecasting tools and data bases in place), growth can be forecast and steps taken to mitigate potential negative impacts. Local governments have expressed their willingness to address the needs which will occur, both in terms of facilities and services. Eventual decommissioning needs can likewise be addressed through good planning, and these potential impacts can be further minimized by continued development of the Billings area's existing diversified economic base through encouragement of a "spin off" high tech component of that economy during the operational years of the SSC project.

A final potential concern relates to the issue of relocating the few property owners affected by the project. The state will work with these property owners to ensure that they are fairly compensated and will aid in any necessary relocation.

5.8.6 Health and Safety

Sting the SSC project in the Comanche Basin area is not believed to present any significant public health and safety problems. Anticipated potential public health and safety impacts are mostly generic, and would occur wherever the project was sited. The relatively low existing population base at the site, will limit the magnitude of these impacts.

Project impacts on air and water quality will be limited and also will be adequately mitigated to ensure no adverse public health and safety effects.

Oher potential public hazards center on increased traffic during both construction and operation. Any such hazards may and will be mitigated by proposed new or improved roads and traffic control to service the site. Other potential operational hazards relate to the transport, storage, and handling of hazardous materials at the SSC facilities. Since only relatively small amounts of such materials will be used, any accidents involving them will be very limited in effect, typically on-site. One possible exception is the transport and storage of large quantities of compressed or liquified gases for cryogenic use. Any associated transport and storage problems associated with these gases are not specific to the Comanche Basin site and indeed are mitigated to some degree by the proposed site's comparatively unpopulated area. Any hazardous waste generated by SSC operations, such as tritiated water and low level radioactive solid waste, also will be small in quantity, and will be handled in a proven safe manner and disposed of only at certified facilities.

DOE has not indicated any public health and safety problems associated with experiments conducted at the facility, provided there is adequate cover for the collider ring.

5.8.7 Noise

With its low population and agricultural land use, the site area is comparatively quiet. Construction will generate considerable heavy equipment noise in active construction areas. Both construction and operation also will increase the volume of rail and highway traffic, along with associated noise. Facility operations themselves will generate relatively little noise, such as pump and compressor sounds.

Noise impacts on wildlife are discussed in Section 5.8.3.2. Long-term noise impacts on the human population are not expected to be appreciable, given the general isolation of most farm residences.

5.8.8 Air Quality

No difficulty is anticipated in complying with all applicable air quality standards for the area.

The air quality of the site is typical of other rural agricultural areas in eastern Montana, where for several months out of the year, the chief problem is with suspended particulates generated by farming and traffic on unpaved roads. Construction at the site will contribute somewhat to total suspended particulates, although this will be substantially mitigated by providing paved access roads to construction areas. Other dust suppression measures also may be appropriate.

Air quality impacts from project operation will consist primarily of vehicle exhaust. There is little that may be done to mitigate the impact, other than ensuring adequate traffic flow in the area.

These impacts, however, are not expected to be particularly significant, given the good dispersion conditions in the area. The relatively high average wind speeds and consequent instability of the atmosphere in the area, together with the lack of any topographic features which could trap air pollutants in stable layers near the surface, ensure that any air pollutants generated at the site will be quickly dispersed.

5.8.9 Historical and Archaeological Resources

The State Historic Preservation Office (SHPO) has identified 13 recorded historical and archaeological resource sites which fall within the sections potentially affected by the project. These include eight tipi rings, three lithic scatters, and three historic structures:

Site Number	Site Type
24 GV 0095	Bridge
24 YL 0004	Tipi ring
24 YL 0005	Tipi ring
24 YL 0006	Tipi ring
24 YL 0007	Tipi ring
24 YL 0009	Tipi ring
24 YL 0010	Tipi ring
24 YL 0011	Tipi ring
24 YL 0019	Lithic scatter
24 YL 0257	Log hotel
24 YL 0563	Lithic scatter/Tipi ring
24 YL 0613	Cribbed log occupation structure
24 YL 1030	Lithic scatter

The only site on the national register of historic places is the former Antelope Stage stop on the original route from Billings to Lavina (24 YL 0257). It is located in T3N, R24E, Section 3, a part of the proposed Area C or campus expansion area. (Id.) Adverse impacts to the structure may be readily avoided through appropriate site design, which could incorporate the historic structure as a positive design element for the campus.

A thorough cultural resource survey of these recorded sites, as well as all affected lands, will be conducted to ensure that impacts on any historical or archaeological resources are prevented or mitigated to the full satisfaction of regulatory authorities. Given the nature of the known and expected cultural resources in the region, this is not expected to pose any significant difficulty to the SSC project.

VOLUME 6

SETTING

6.1 GENERAL

6.1.1 Site Location

The proposed site location is north-northwest of Billings, Montana, with the nearest point on the ring about 12 miles, and the campus 25 miles, from Billings Logan International Airport. Most of the ring is in Yellowstone County, with the remainder in parts of Stillwater, Golden Valley and Musselshell counties. The largest town within the ring, with a population of about 150, is Broadview. Acton and Comanche are small settlements with few buildings or residences. Major highways such as Interstate 90 and US 87 serve the site.

The collider ring centers on the Broadview East quadrangle map. It is broadly located at the intersection of perpendicular lines 31,800 feet south of the Broadview school and 15,100 feet west of State Highway 3. The center of the ring is in the Northeast quarter of the Northwest quarter of Section 15, Township 3 North, Range 23 East, as shown on the Broadview East quadrangle map. It is at Longitude 108° 51' 14" and Latitude 46° 00' 54". The longitudinal axis lies at 26° 31' 08" west of true north.

The site is located in what is known locally as the Comanche Basin. This basin is shallow with its east rim at about elevation 4000 feet, the west side approaching elevation 4200 feet, the north and south edges at 3800 feet and the low points within the basin at about elevation 3750 feet.

Figure 6.1-1 provides a general location of the site in perspective to Billings. Figure 3.1-3 in the map folder shows the site with respect to the generally flat but gently sloping basin topography.

Figure 6.1-2 provides aerial views of the campus, north arc and southwestern section of the ring. Highway 3, the railroad and Broadview can be seen in at least one of the views. The photos characterize the general topography, land use and transient wetland areas of the site.

6.1.2 Site Layout

The facilities were located with the following goals preeminent:

- Keeping the tunnel level as much as possible, with a minimum tilt. There is no undulation of the tunnel profile.

- Minimizing the depth of structures at experimental stations, first, and access buildings second;
- Providing a stable foundation for the tunnel;
- Minimizing surface disruption from excessive cut and cover while providing just enough cut and cover locations to make construction access at certain points around the ring convenient for efficient tunnel boring and spoil removal operations.

A balance of all the objectives has been achieved. Please refer in Volume 3 to Figures 3.1-2, a tunnel length-overburden depth histogram, and Figures 3.1-3 and 3.1-4, the 1:24,000 plan and profile layouts of the collider ring found in the separate map folder.

6.1.2.1 **Vertical Placement Flexibility**

A number of trial orientations and profiles were examined to determine the best orientation of the collider. Within the time constraints of preparing the proposal, the proposed arrangement is a suitable location and profile. Further refinements will be possible; however, this should probably be done by DOE as part of the final design. Structure depths could be reduced by undulating the ring somewhat, but at this point the project may be better served by having minimum disruption of tunnel alignment.

The only constraint in the vertical alignment of the tunnel is the elevation of the Burlington Northern Railroad as it passes over the northern and southern arcs of the tunnel. At the northern arc, the railroad grade is at an elevation of 3785 feet and at the southern arc, the elevation is 3800 feet. The railroad and highway appear to follow a straight plane throughout this 17-mile section between the tunnel arcs. The tunnel centerline is located 50 feet below the rail grade and highway at these points. This was done to keep these points in stratified fee. There is no need to relocate either the highway or railroad as it passes through the site.

The ring is configured in two horizontal and one sloping planes. The sloping plane tilts from west to east at 0.5 degrees and the sloping sections are confined to equal 32,000 foot sections of the north and south arcs. The longitudinal axis of this sloping plane is skewed in plan view 10.8 degrees from the longitudinal axis of the collider ring. This skewing is caused by the position of the highway and railroad as it is presently planned to pass over the ring. The ring can be rotated to eliminate the skew if it is technically advisable.

The histogram of tunnel depth versus length indicates that about 6 percent of the ring is 50 feet or less in depth, 50 percent is less than 120 feet, and no point is greater than 290 feet. The deepest accessway E8, is 255 feet from grade to the centerline of the ring. The average depth of the other nine access buildings is only 115 feet. A fully surface excavated tunnel would be disruptive to farming, and land and mitigation costs could equal or exceed any savings in construction. While the flexibility exists to increase cut and cover percentages, it must be weighed against a more articulated tunnel profile and greater surface mitigation costs.

6.1.2.2 Horizontal Placement Flexibility

The 7.5 minute quadrangle maps show that the tunnel orientation is greatly influenced by the Comanche Basin topography. The position of the railroad influences the decision to locate the campus and cluster halls either to the east or west. Since the east location is closer to Highway 3 and Billings, this was chosen as the preferred location for the campus. The terrain on the east side of the collider is generally flatter than the west and the campus site work would be cheaper on the east side.

The quadrangle maps also show that there is sufficient flexibility to translate the collider a half mile or more one way or the other, and perhaps rotate its axis a few degrees. The constraints tend to be the terrain ridges and more rugged topography to the northwest, northeast and southeast.

The land owners do not appear to object to moving the ring. Land owners were interviewed concerning this at least a mile or more beyond the proposed site boundaries.

The two 500 kV transmission line circuits, discussed in Volume 8, will pass close to the southern edge of Area C; and therefore, some minor adjustment may be necessary to avoid moving these lines. The lines and the campus facilities can exist as proposed. Certain land owners in the campus area own large blocks of land. Interviews with them have indicated that if their land were purchased, they want more purchased than the minimum indicated in Table 2.1-1. If their entire tracts were purchased, DOE would have considerable flexibility to locate campus facilities without moving the 500 kV transmission lines. This additional acreage in the campus area could amount to close to 3,000 additional acres, giving DOE considerable design flexibility. The same situation will exist in the west cluster area, but with smaller tracts.

6.1.3 Site Area Features

6.1.3.1 Man-made Features

Man-made features on the site consist of approximately three dozen structures, including residences, barns, silos and sheds. Ten currently occupied residences are located on the ring. The quadrangle maps have been marked to indicate that only eight landowners have buildings that must be moved or razed. Two residences lie over stratified fee land. There may be a dozen or so abandoned structures such as old farm houses and barns that dot the site in areas of stratified fee, some of which might be razed and others ignored.

The town of Broadview, located inside the ring toward its northern end, has a population of about 150. It has a 12-grade school, small motel, two bars, a gas station, grain elevators, and some residences. Access to the site will miss Broadview entirely. Most of the construction personnel will travel the 25 miles from Billings (25 miles to the campus area) and will follow a new access road north from Acton totally avoiding Broadview. Personnel coming from the north will probably approach the campus or west cluster areas from county roads exiting from Route 3 north of Broadview. Refer to Volume 4, Section 4.2, for transportation maps of the area.

Acton and Comanche consist of only a few structures. One oil pipeline traverses the east portion of the site. Owned by U.S. Consolidated Oil Company, it is a 16-inch buried line that could be moved if it affected campus facilities. Depending upon the detailed layout of campus facilities, the pipeline location may or may not impact the project.

One natural gas well is in Sec. 35, R22E, TSN, about a mile north of tunnel access structure E8. A 3-inch plastic gas line is said to run south-southwest from the well toward Rapelje. It probably intersects the ring in two places. It is not known if the line is active, and the exact location is not known at this time. It is estimated that this line passes over stratified fee tunnel sections and should have no impacts on construction or operation.

The railroad and Highway 3 are features that provide positive impacts to the site. The railroad runs about one to three trains per day over this line, which connects Great Falls and Billings and points south and west. This line should be of benefit to supply materials directly to the site, particularly heavy segments of detectors. A spur could easily be constructed to accommodate the delivery of materials closer to the experimental areas. It is recommended that such a spur be constructed west of, and parallel to, the new access road to the campus which would depart from route 3 just north of Acton. The railroad and highway are a number of miles away from the collision rails so that vibration will not be a factor.

The transmission lines which pass through the site will be of benefit to the project while causing no adverse effects. Two 500 kV transmission lines pass through the site as do other lines of 230 kV and 100 kV or less. A major substation is south of Broadview and west of Highway 3 about 6 1/2 miles west of the campus. From this substation, power lines can be constructed which will supply power to the necessary sections of the ring. This substation completely minimizes transmission impacts, since there will be none outside the boundaries of the ring.

6.1.3.2 Natural Features

There are no significant natural features that would adversely affect this site. The area is a shallow basin, with no natural drainage outlets. Flooding is not a concern. The low points of the basin are at the northern and southern arc areas adjacent to the railroad. All major SSC facilities will be higher than these low points. Some natural low areas form ponds during extremely wet seasons, which will harbor waterfowl during these periods. One natural depression collected local runoff sufficient to freeze in the winter and formed a floating sheet of ice which threatened the guyed Vee 500 kV transmission towers. Montana Power rerouted one circuit to higher ground where ice would not form, and the second circuit was protected with pile bollards around the tower bases. Because rainfall is minimal in this area (about 11 inches per year), ponding within the basin is not considered a problem. Even in the one area where a transitional pond will form above the northeast section of the tunnel arc, there will be no problem because the tunnel will be bored in that area, and the water will not percolate through the alluvium and underlying rock. See Volume 5 for more information on surface water and waterfowl.

6.1.4 Summary

There are no features, man-made or natural, which will have any negative impact on the project. Most features, such as roads, transmission lines, and railroad, will be of benefit to the project. A 7-mile railroad spur from Acton, parallel to the main access road to the east cluster area, would provide excellent construction and material delivery support. A network of county roads connect the farms and residences around the ring, and will be of great benefit during construction to provide low impact access to various points around the ring for construction. Highway 3, which will be upgraded by the State, will provide excellent access between Billings and the site during construction and operation. Disposal of spoil will not be a problem, since it is highly suitable for road upgrades and leveling of construction areas around the ring.

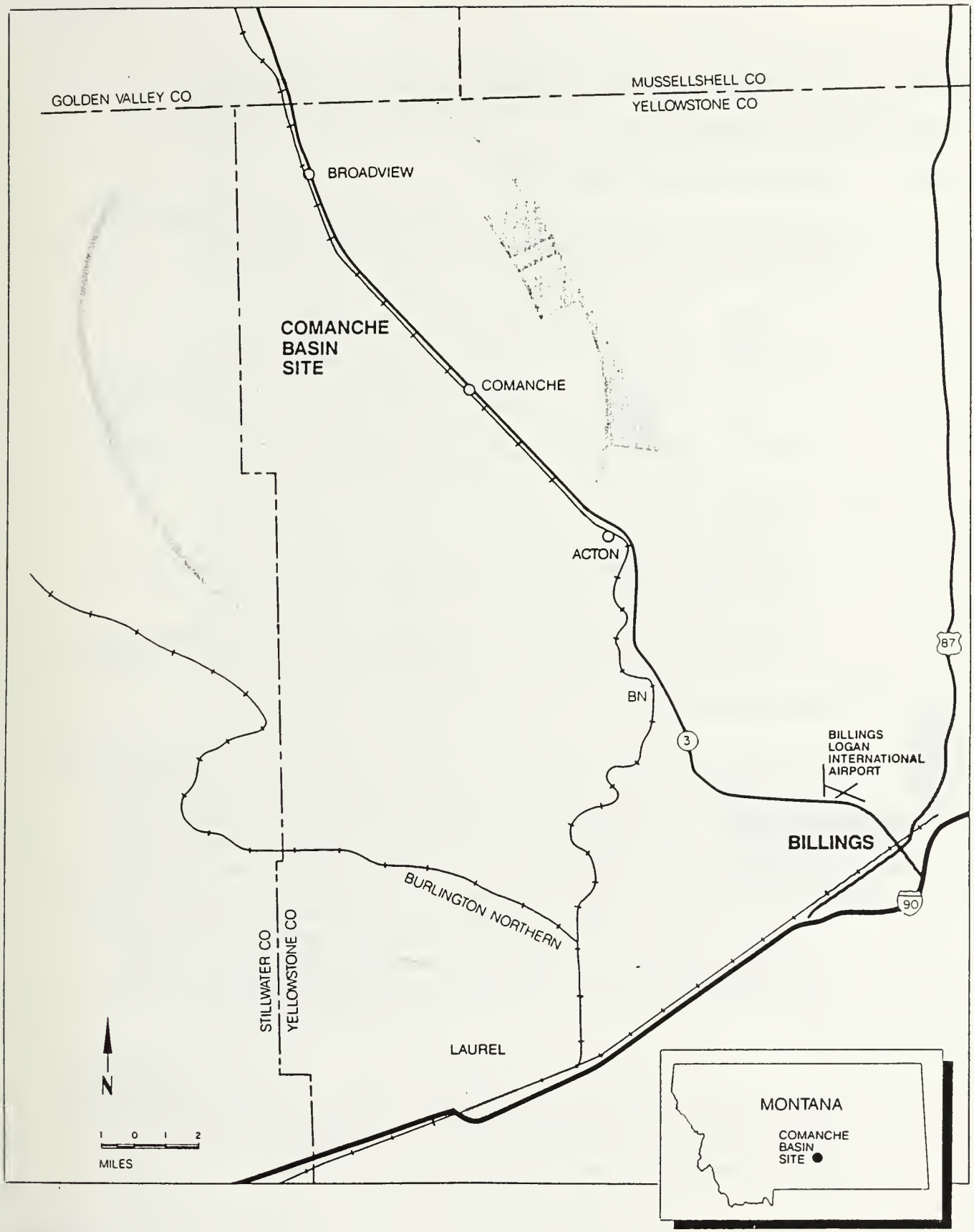

Figure 6.1-1 COMANCHE BASIN SSC SITING AREA

6.2 REAL ESTATE ACQUISITION PLAN

6.2.1 Scope of Acquisition

6.2.1.1 Number of Acres by Types of Estate

The area of land to be conveyed and types of conveyance (estates) and acres contained within existing roadways, utility easements, etc., are approximately as follows:

8,470	Acres shall be conveyed in fee simple.
7,680	Acres shall be conveyed in stratified fee estate.
(40)	Acres of the surface estates above are estimated to comprise existing roadways which will be used for access within the project area. ( ) = Included in other acreage.
(3)	Acres comprise existing Burlington Northern Railroad rights-of-way as it passes across the ring. This area is included in the stratified fee areas.
16,150	Total

The additional land required for relocated roads, utility easements or new railroad spurs is estimated to be less than 250 acres.

Table 2.1-1 (Volume 2) lists estates by project area. See also Figure 3.1-3 in the map folder for a specific delineation of land to be offered.

6.2.1.2 Parcel Ownerships

Most of the land in the siting area is privately owned. In this area, the state owns about two sections in each township. The BLM generally owns 3 to 4 sections per township; however, for the particular site selected, only one parcel is administered by the BLM. Landownership patterns are shown on Figure 6.2-1. A total of 257 owners have been identified over about a 350-square-mile area within the collider ring or within a few miles of it. Only 72 owners are directly impacted by land acquisitions for the project; 70 are private, and 2 are governmental owners. Eight owners would be forced to relocate or abandon residences and other improvements at 9 locations. Another two, who own residences above stratified fee land, may retain ownership of their homes, but with wells that must be relocated. The location of each of the 10 land owners is shown on Figure 3.1-3 in the map folder.

In general, this site should have minimal landowner impacts compared with many other states. Approximately 153 parcels will be acquired in fee simple from 72 owners. Approximately 63 parcels will be acquired from 48 of the same 72 owners by stratified fee estate. Two parcels will be acquired in stratified estate from the Burlington Northern Railroad.

The number of parcels and owners from which additional utility easements may be obtained cannot be determined until final design. However, existing utility rights of way will be used and few, if any, new owners would be impacted. Only one new right-of-way may be needed from the Broadway substation to the west cluster, about 9 miles.

6.2.1.3 Governmental Ownerships

The State of Montana owns 11 parcels of land intersected by the ring, and the Federal Fish and Wildlife Service has one road and one wildlife management pond on the north arc of the collider.

A number of county roads pass over the ring. The bulk of these pass over areas of stratified fee ownership. In a few cases, near the campus, county roads may have to be rerouted to provide access to beam dump areas, and also to landowners east of the east cluster area.

6.2.1.4 Siting Area Improvements, Relocation and Mitigation Measures

The proposed configuration of the site is shown at 7.5-minute scale on Figure 3.1-3 in the map folder. The maps represent fairly accurate county road information. The maps also show transmission lines that cross the area as well as the Burlington Northern Railroad at State Highway 3. Figure 4.2-3 in Volume 4 shows county roads in more detail. There is one small cemetery shown west of the town of Comanche, but it will not be impacted. There are buried telephone lines, and local power distribution lines run overhead adjacent to many of the county roads. One oil pipeline, owned by U.S. Consolidated Oil Company, passes through the easterly campus area of the site. Two to four miles of the pipeline might have to be relocated by DOE depending upon the final layout of the site.

We anticipate that nine residential units owned by eight families and farming corporations will need to be relocated or razed on the eastern side of the ring, and one unit displaced on the southwest side. Two other residents own buildings over stratified fee sections, one in area I to the southeast, and the other near area E4. These owners should not be impacted other than potential well relocations. Two other wells are shown in areas of stratified fee with no residences. There may be stock water wells, that if currently active, might have to be moved at State expense. In actuality there is very little disturbance to farm life and landowners for this particular site. The land blocks have tended to be reasonably large with an average ownership of about 270 acres for each of the 70 private landowners affected by the project.

Photographs of some of the impacted properties are shown on Figure 6.2-2. Landowners whose improvements and residences lie in surface fee estates to be donated to the project are identified by landowner number code on the quadrangle maps (Figure 3.1-3) in the map folder.

6.2.1.5 Units Qualifying for Relocation Assistance

All of the owners of nine residences will be eligible for relocation assistance under the Uniform Relocation Assistance and Real Property Acquisition Policies of 1970 (Public Law 91-646). All of these residences are on farm or ranch units, some of which will have to be relocated in their entirety or razed. No roads, cemeteries, communication or utility lines would have to be relocated. Facilities which may have to be relocated are those typical of agricultural operations in the area, such as corrals, sheds, graneries, and barns. The residences may be used by the department for temporary office space or other project uses. Other structures may be useable for temporary storage of vehicles or equipment associated with project construction.

6.2.2 Method of Site Acquisition

Montana's site acquisition plan is outlined in detail below.

6.2.2.1 Description of Site Acquisition Procedures

There are three types of ownership patterns within the proposed site: fee, state and federal lands. Fee land will be acquired either by a public or quasi-public corporation established for that purpose or by the state in compliance with the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 and supporting regulations. A total of 72 landowners would be affected by the proposed project. Stratified fee estate would be acquired from 48 landowners for 7,680 acres. The remaining 8,470 acres would be acquired from 72 landowners as fee simple titles for both surface and subsurface disturbance. If Montana is selected as one of the best qualified sites, additional steps will be initiated to assure timely land availability. First, Montana will provide DOE rights of entry from the landowners. In addition, Montana will begin the appraisal process at this time, and will start to acquire options for the stratified fee estate from the affected landowners. The governor will call a special session of the legislature to provide the necessary appropriation and amendments to the statutes.

If Montana is chosen as the preferred site in July, 1988, appraisals will be completed and Montana will start to acquire options from the remaining landowners. In addition, surveys will be initiated, easement options will be acquired, and the specific details of a relocation plan for the 10 residences will be developed. If Montana is selected as the final site, additional support staff will be hired by the state to assure timely availability of land to the DOE.

Once selected as the final site, Montana will immediately provide a 100-acre housing site for the DOE. At this point, all previously acquired options will be exercised, placing the greatest priority on the campus area and the quarter of the ring as designated by DOE. Land surveys will be completed, the relocation plan will be implemented, and a preliminary title report will be presented. Condemnation actions, if necessary, for the campus and the first quarter of the ring will be initiated at that time.

In April, as required by DOE, Montana will submit the survey report, the preliminary title report and the Offer to Donate Real Property (DOE's Appendix G) to the DOE. By July 1, 1989, Montana will have completed the 10 relocations necessary and will provide title to the DOE, as indicated in the DOE timetable for acquisition.

State school trust land can be transferred from state ownership only by exchange or by sale at a public auction. Montana will exchange these school trust lands with the BLM. If Montana is selected for the best qualified list, tracts will be identified for exchange between the agencies in January 1988. Mineral and cultural reports will be prepared and surface lessees will be notified of the potential exchange. If Montana is the preferred site, the Department of State Lands will initiate preliminary approval of the proposed exchange in August 1988, and a public hearing will be scheduled in September in the counties affected by the exchange.

Under the exchange procedures, the Montana and National Environmental Policy Acts must be complied with. Therefore, in September, a Land Report, supplementing the Department of Energy EIS as necessary for land acquisition, will be published.

If Montana is selected as a final site, the Department of State Lands will give final approval for the proposed exchange and BLM will publish a record of decision. A Notice of Realty Action will then be published by the BLM for 60 days. The BLM will then provide a permit for the use of those lands to the DOE. Title will pass when Montana is selected as the final site prior to issuance of a land use permit. See also Section 6.2.2.4.

Federal lands intersected by the ring are managed by the U.S. Fish and Wildlife Service (USFWS) for waterfowl production and will require a right-of-way permit. At this particular site, the tunnel will be 50 or more feet below the surface and no related surface disturbance is proposed. Therefore, the USFWS would provide a permit to the DOE for use of the stratified estate.

6.2.2.2 Summary of Existing Legislation

Existing and proposed legislation are addressed in Section 2.1.4.

6.2.2.3 Condemnation Authority

Condemnation authority does exist, and procedures concerning its use are discussed in Volume 2, Section 2.1.4.

6.2.2.4 Method of Transferring Federal Lands to DOE

About 7 square miles of public land, administered by the BLM, are located about 2 miles east of the E1-J1 Section of the east cluster. These lands are not segregated in any way that limits their availability for this project. Application for Withdrawal (Sec. 204 P.L. 94-579) by DOE will immediately commit the land for 2 years, during which time the Department of the Interior will process the formal land withdrawal should this land be of interest to DOE.

Another parcel, belonging to the USFWS, intersects the north collider arc 1 1/2 miles east of Highway 3. The stratified fee estate needed under this parcel will be transferred to the DOE using the USFWS right-of-way format with special conditions, as defined in a letter to the state from the USFWS dated August 3, 1987. Special conditions are provided for under Title 50 of the Code of Federal Regulations. See also Section 6.2.2.1.

6.2.2.5 Situations Requiring Federal Eminent Domain Assistance

- Intercession - The BLM may be called upon to acquire lands through either state or private exchange which, once in federal ownership, will be made available to DOE through Sec. 204 P.L. 94-579 withdrawal. BLM administrative costs of processing will be paid by the state.

- Eminent Domain - If the BLM were unable to exchange public land for all of the state school trust lands, and to transfer sufficient control or use permits to the DOE, these school trust lands would have to be condemned using the federa' power of eminent domain.

Montana will contract directly with independent contractors for legal and appraisal services. Montana will reimburse DOE for all expenses, including acquisition costs, salaries, contractor fees, and incidental expenses incurred as a result of condemnation proceedings. See the Montana Legislature Statement of Support in which the legislators have committed their support for appropriations necessary for land acquisition. This exhibit is included in Section 4.10 of Volume 4.

6.2.2.6 Qualifications of Real Property Acquisition Personnel

Real property acquisition and relocation assistance activities will be handled or directed by personnel of the Right-of-Way Bureau of the Montana Department of Highways. This organization acquires interest in real property and provides relocation assistance services and payments for all federal aid highway projects in the state of Montana. These services are all performed under the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 (Public Law 91-646).

The Right-of-Way Bureau has also provided relocation assistance services for other federal and state agencies, including the Federal Aviation Administration and the Montana Department of Fish, Wildlife, and Parks.

Acquisition and relocation assistance will be managed by the section supervisors in charge of the department's appraisal, acquisition, relocation assistance, and other applicable functions. The personnel in these positions all have 15 - 30 years experience in performing and managing eminent domain real property acquisition and relocation assistance. They are completely familiar with and experienced in acquisition and relocation assistance under Public Law 91-646.

Appraisals, appraisal review, acquisition (negotiation), and relocation assistance will be performed by 6 to 10 staff appraisers, review appraisers, and acquisition agents from the Montana Department of Highways. These employees have two or more years of experience in eminent domain acquisition and relocation assistance under Public Law 91-646.

Appraisal and negotiation activities may be supplemented by the use of fee appraisers and private land acquisition companies if deemed necessary. Fee appraisers will be selected from the Department of Highways list of approved fee appraisers. These appraisers usually have MAI, SREA, or SRA designations. Fee appraisers and private land acquisition companies used for this project will be directed by the management team.

The following personnel will be assigned to manage real property acquisition and relocation assistance:

Appraisals: Chief Appraiser

Experience:
Chief Appraiser for Department of Highways - 9 years
Assistant Chief Appraiser - 8 years
Land Acquisition Agent for Department of Highways (Appraisals and Negotiations) - 7 years

Acquisition: Chief Negotiator

Experience:
Chief Negotiator for Montana Department of Highways - 1 month
Assistant Chief Negotiator - 9 years
Acquisition Agent for Department of Highways (Appraiser and Negotiator) - 18 years

Relocation Assistance: Relocation Manager

Experience:
Relocation Manager for Montana Department of Highways (Includes actual performance of relocation assistance activities) - 6 years
Plans Coordinator (Right-of-Way Engineering) - 5 years
Field Engineering (Survey) for Department - 2 years

Field Project Supervisor: Field Right-of-Way Section Supervisor

Experience:
District Right-of-Way Supervisor for Department of Highways - 13 years
Review Appraiser for Department - 5 years
Acquisition Agent (Appraiser and Negotiator) - 10 years

Titles and Closing:

Experience:
Land Section Supervisor (Titles and Closing and Property Management) for Department of Highways - 4 years
Assistance Land Section Supervisor - 10 years
Plans Section Supervisor (Right-of-Way Engineering and Legal descriptions) - 4 years
Plans Coordinator (Right-of-Way Engineering) - 2 years
Acquisition Agent (Appraiser & Negotiator) - 4 years

Appraisals will be prepared by three to six appraisers who are either staff members of the Right-of-Way Bureau or fee appraisers. Staff appraisers will have three or more years experience in appraising under Public Law 91-646. Fee appraisers will be selected from the Department of Highways list of qualified appraisers. Most of these fee appraisers have professional designations as MAI, SREA, or SRA.

Appraisal review will be performed by one to two Right-of-Way Bureau staff review appraisers who have had 3 or more years of experience as reviewer appraisers working under Public Law 91-646.

Acquisition (negotiations) and relocation assistance will be performed by four to eight Right-of-Way Bureau staff right-of-way agents having 2 or more years of experience in eminent domain land acquisition under Public Law 91-646. Negotiations may also be contracted to one or more private land acquisition firms who would work under the close direction of highway department project management personnel.

Any necessary property boundary surveys will be performed by registered land surveyors under the direction of the Department of Highways surveying manager.

6.2.3 Schedule of Real Estate Acquisitions

6.2.3.1 Major Milestone Activities

The following is an overall schedule of all activities (shown also on Figure 6.2-3):

BQL is published in December 1987

December 1987:	Montana will provide a right of entry for DOE assessments. Representative appraisals will be made, state liaison will be appointed to work with DOE.
January 1988:	A budget will be developed and Governor Schwinden will call a special session of the legislature to fund Montana's land acquisition plan. A team will be appointed to implement the plan. Land exchange parcels will be identified.
February 1988:	The appointed team will begin (1) to appraise all parcels, (2) to acquire options, (3) to negotiate land prices and (4) finish identifying mineral owners.

June 1988:	Any necessary condemnation actions will be identified.
July 1988:	The DOE will identify a preferred site. The Montana acquisition team will finalize negotiations, begin surveys of the parcels to be acquired, acquire options for easements and rights-of-way.
August 1988:	The Acquisition Team will plan the relocation of the 10 residences identified and begin to obtain commitments of non-entry from mineral owners of split estates. The state's liaison will assure MEPA compliance at the draft EIS stage. Exchange proceedings for state-owned lands would begin.
September 1988:	EA/Land Report will be published. Application for U.S. FWS permits submitted.
November 1988:	DHES permits for temporary housing will be applied for.
January 1989:	DOE will select the final site. Surveys will be completed, preliminary title reports begun, relocations initiated and a 100-acre housing site would be provide to the DOE. Condemnations will be filed. Notice of Realty Action will be published by the BLM. The governor will, by executive order, create an interagency task force to facilitate permitting actions. Montana will begin exercising options. Final highway improvement construction plans will be developed and initiated. Rural SID will be established.
April 1989:	DOE will be provided with the completed surveys, the preliminary title report, and the Offer to Provide Transfer of Real Property to the Federal Government. Montana will initiate resolution of any potential title problems. Permits from federal agencies will be applied for.
July 1, 1989:	Montana will provide DOE with title to the first quarter of the ring and the campus area and will provide a title report and the necessary title insurance. All relocations will be completed at this time.

Beyond this point, Montana will follow the above steps, as needed, to transfer land for the remaining quarters, as described in Section 2.4. The following sections highlight key dates of concern to DOE.

6.2.3.2 Appraisals

Appraisals will be completed by July 1988.

6.2.3.3 Surveys

The surveys of the proposed site will be completed in March 1989.

6.2.3.4 Preliminary Title Evidence

A required by DOE, preliminary title evidence will be provided on April 1, 1989.

6.2.3.5 Commencement of Negotiations

Negotiations will begin in February 1988.

6.2.3.6 Condemnations

Montana will initiate condemnation actions, if necessary, in January 1989.

6.2.3.7 Acquisition

Acquisition of the site will be completed in accordance with the schedule outlined in Section 2.4. However, much of the acquisition of the last three-quarters of the land would actually be completed in 1989 simply because of work scheduling considerations.

6.2.3.8 Completion of Relocations of Residence and Businesses

Relocations will be completed in accordance with Public Law 91-646 by July 1989.

6.2.3.9 Completion of Relocation of Infrastructures

No relocations are expected.

6.2.3.10 Areas of Potential Delay

No areas of potential delay are expected except those which may be caused by a shift in the DOE's Schedule.

VOLUME 7

REGIONAL CONDITIONS

7.1 VIBRATION

The existing sources of vibration in the Comanche Basin include automobile traffic on the highway and the county roads in the area, trains traveling on the railroad which traverses the basin, and operation of agricultural machinery by farmers in the area.

Because the area is rural and agricultural, there are fewer sources of vibration than in more populated areas. Automobile traffic in the Comanche Basin is mostly confined to State Highway 3, which crosses the basin from Acton to Broadview. The average volume of traffic on this highway is 1450 to 1800 vehicles per day (Duset, 1987). Nowhere is the highway closer than about five miles to the interaction points on the collider ring. The county roads in the basin are primarily used by farmers and ranchers in the area for access to their property. There is much less traffic on the county roads than on Highway 3. Because the county roads generally are unpaved, traffic is slower as well.

On average, one to two trains use the Burlington Northern Railroad line each day (Keim, 1987). These trains generally are about 80 cars in length and travel about 60 miles per hour as they cross the basin. The closest approach of the railroad tracks to the interaction points on the collider ring is about five miles.

The farmers in the Comanche Basin use heavy machinery, including tractors, cultivators, and combines, to cultivate and harvest their crops. Such activities probably would not take place near the interaction zones, however, because of the presence of the campus facilities in these areas.

7.2 NOISE

The Comanche Basin is a rural, agricultural area which does not experience unusual levels of background noise. The principal sources of noise in the area are automobile traffic on Highway 3, train traffic on the railroad line which crosses the basin, and noise from the agricultural machinery used by farmers in the area. Noise from aircraft taking off from the Billings Airport will occasionally be audible, but since the principal corridors used by aircraft are 10 to 15 miles from the Comanche Basin, aircraft noise should not be objectionable. There are no sensitive receptors such as hospitals in the Comanche Basin.

Levels of noise in the Comanche Basin will increase during construction of the SSC, primarily because of the heavy machinery to be used and the increase in traffic to the construction sites. After the SSC is in place, there will be some increase in noise above current levels because of the increased automobile traffic in the area.

7.3 CLIMATIC CONDITIONS

The climate of Billings, Montana, is strongly influenced by the nearby Rocky Mountains, which moderate the continental type of weather. Air moving eastward from the Pacific Ocean flows over the Rocky Mountains, and when this air descends the eastern slopes of these mountains, it is compressed and becomes warmer. As a result, south-central Montana enjoys a climate that is mild compared with cities of similar latitude to the east. The average January temperature in Billings, for example, is nine degrees warmer than Minneapolis (see Figure 7.3-1).

Mild weather during the winter occurs when warm "chinook" winds blow from the Rocky Mountains. Occasionally, colder arctic air arrives from the north, but cold periods generally are short, usually lasting for no more than 3 or 4 days. Billings frequently has mild, "open" winters when arctic cold bypasses the area completely. Snowfall generally is light because of the frequent periods of warm weather, and snow seldom accumulates to significant depths. During the winter, the ground normally is free of snow about 34 percent of the time (see Table 7.3-6).

Spring generally brings rapid changes in the weather, with frequent periods of sunny, mild weather and occasional periods of rain or wet snow. The last spring frost in the area normally occurs in mid-May.

Summers are warm, sunny, and dry, with occasional afternoon and evening thunderstorms. High temperatures in the summer normally are in the 80's. Unpleasantly hot weather is uncommon. Because of the low humidity, summer nights are cool, with low temperatures normally in the 50's.

During autumn, the days are mild and the nights cool. The first frost of the autumn season generally occurs about September 25, and is typically followed by an "Indian summer." The transition to winter usually takes place in late November or early December.

Records of meteorological conditions, including temperature, humidity, precipitation, and wind, have been kept by the National Weather Service (NWS) at Billings Logan International Airport since 1934. This airport, approximately 15 miles southeast of the proposed site, at an elevation of 3567 feet, is in an area topographically similar to the site, and consequently the data collected there are representative of the Acton-Broadview area. Table 7.3-1 provides a summary of monthly and annual average temperature, humidity and precipitation for the period 1951-1980, as recorded at Billings Logan International Airport.

Records of temperature and precipitation have been kept by a cooperative observer at Broadview for the National Oceanic and Atmospheric Administration (NOAA) since 1951. These data, while less comprehensive than those from the Billings Airport, provide the most representative data for the site. Summaries of monthly and annual climatological normals, means, and extremes for these two locations for the standard climatological averaging period of 1951 through 1980 are shown in Tables 7.3-2 and 7.3-3.

7.3.1 Temperature, Humidity, and Precipitation

Average annual temperature, humidity, and precipitation for Billings is shown in Table 7.3-1. During the winter months of December, January, and February, average high temperatures in Billings range from 29.9 degrees in January to 37.9 degrees in February. The average low temperatures range from 11.8 degrees in January to 18.8 degrees in February.

The high temperature normally is 32 degrees or higher on an average of 19 days in December, 16 days in January, and 20 days in February. The low temperature typically is 32 degrees or colder on 28 days in December and January, and 24 days in February. Low temperatures below zero normally occur on 5 days in December, 9 days in January, and 3 days in February.

At Broadview during the winter, average high temperatures range from 32.3 degrees in January to 39.4 degrees in February. The average low temperatures vary from 7.9 degrees in January to 15.5 degrees in February.

In the spring months of March, April, and May, average monthly high temperatures in Billings warm from 44.0 degrees in March to 66.4 degrees in May. The average monthly low temperatures range from 23.6 degrees in March to 43.3 degrees in May. The high temperature normally is less than 32 degrees on an average of 5 days in March and 1 day in April. Low temperatures of 32 degrees or colder normally occur on 24 days in March, 13 days in April, and 2 days in May. Low temperatures below zero normally occur on 1 day in March.

During the spring at Broadview, average monthly high temperatures increase from 45.5 degrees in March to 67.0 degrees in May. The average monthly low temperatures range from 19.9 degrees in March to 39.9 degrees in May.

Table 7.3-1

Average Temperature, Humidity, and Precipitation

Billings WSO AP, Montana

1951 - 1980

Month	Temperature Ave High	Temperature Ave Low	Temperature Ave	Humidity Hour (Local time) 5	11	17	23	Precipitation Ave Precip	Ave Snow
Jan	29.9	11.8	20.9	65	61	57	64	0.97	11.6
Feb	37.9	18.8	28.4	65	58	51	62	0.71	8.2
Mar	44.0	23.6	33.8	68	54	46	62	1.05	10.1
Apr	55.9	33.2	44.5	67	48	40	58	1.93	9.2
May	66.4	44.3	54.9	69	48	42	59	2.39	1.2
Jun	76.3	51.6	64.0	71	46	40	59	2.07	0.0
Jul	86.6	58.0	72.3	63	39	31	49	0.85	0.0
Aug	84.3	56.2	70.3	61	39	30	46	1.05	0.0
Sep	72.3	46.5	59.4	65	48	38	54	1.26	1.0
Oct	61.0	37.5	49.3	63	49	42	56	1.16	3.8
Nov	44.4	25.5	35.0	66	58	54	62	0.85	7.3
Dec	36.0	18.2	27.1	65	61	58	63	0.80	9.4
Year	57.9	35.4	46.6	66	51	44	58	15.09	62.0

Sources: Local Climatological Data Annual Summary with Comparative Data. Billings, Montana, 1985; Climatological Data Montana 1951 - 1980.

Table 7.3-2

Average Temperature and Precipitation

Broadview, Montana

1951 - 1980

Month	Temperature			Precipitation	
	Ave High	Ave Low	Ave	Ave Precip	Ave Snow
Jan	32.3	7.9	20.1	0.59	8.4
Feb	39.4	15.5	27.3	0.46	6.8
Mar	45.5	19.9	32.8	0.71	6.3
Apr	55.8	30.0	43.2	1.57	6.5
May	67.0	39.9	53.6	2.65	0.2
Jun	76.2	47.7	62.0	2.45	0.0
Jul	86.0	53.1	69.6	0.97	0.0
Aug	84.3	51.1	67.7	1.30	0.0
Sep	72.3	41.7	57.1	1.22	0.4
Oct	62.3	33.2	47.8	0.99	2.3
Nov	45.6	21.4	33.5	0.64	6.6
Dec	38.5	14.6	26.8	0.43	4.6
Year	58.8	31.3	45.1	13.99	42.1

Source: Climatological Data Montana 1951-1980.

Table 7.3-3

Average Degree-Days, Frost Penetration, and Snow Depth

Billings WSO AP, Montana

Month	Average Degree Days (Base 65°F) Heating	Cooling	Average Frost Penetration (inches)	Average Snow Depth (inches)
Jan	1367	0	8-20	3.2
Feb	1025	0	8-20	2.3
Mar	967	0	0-4	1.3
Apr	612	0	0	0.3
May	318	0	0	0.0
Jun	111	81	0	0.0
Jul	9	235	0	0.0
Aug	27	191	0	0.0
Sep	214	46	0	0.0
Oct	487	0	0	0.1
Nov	900	0	0-4	0.9
Dec	1175	0	8-20	1.9
Year	7212	553	----	0.8

Source: Local Climatological Data Annual Summary With Comparative Data Billings, Montana, 1985.

Average monthly high temperatures in Billings during the summer months of June, July, and August range from 76.3 degrees in June to 86.6 degrees in July. The average monthly low temperatures range from 51.6 degrees in June to 58.0 degrees in July. The high temperatures in Billings are 90 degrees or higher on an average of 3 days in June, 13 days in July, and 11 days in August.

At Broadview, the average monthly high temperatures in summer range from 76.2 degrees in June to 86.0 degrees in July. The average monthly low temperatures at Broadview during the summer range from 47.7 degrees in June to 53.1 degrees in July.

During the autumn months of September, October, and November, the average monthly high temperatures in Billings vary from 72.3 degrees in September to 44.4 degrees in November. The average monthly low temperatures during the autumn vary from 46.5 degrees in September to 25.5 degrees in November. The high temperatures in Billings are 90 degrees or greater on an average of 2 days in September. High temperatures of 32 degrees or less occur on an average of 1 day in October and 6 days in November. Low temperatures are 32 degrees or colder on an average of 2 days in September, 8 days in October, and 22 days in November. Low temperatures below zero normally occur on one day in November.

During the autumn months at Broadview, the average monthly high temperatures range from 72.3 degrees in September to 45.6 degrees in November. The average monthly low temperatures in Broadview during the autumn range from 41.7 degrees in September to 21.4 degrees in November.

The average relative humidity during the nighttime hours is nearly constant throughout the year. At the Billings Airport, the average monthly relative humidity during hour 5 ranges from 61 percent in August to 71 percent during June. During hour 23, the average monthly relative humidity ranges from 46 percent in August to 64 percent in January.

Relative humidity during the daylight hours varies more from month to month, with the summer months being the driest. The average monthly relative humidity during hour 11 varies from 39 percent in July and August to 61 percent in December and January. During hour 17, the average monthly relative humidity ranges from 30 percent in August to 58 percent in December.

The average annual precipitation at the Billings Airport is 15.09 inches. About half of the year's precipitation normally falls in April through June. May is the wettest month at Billings, with an average precipitation of 2.39 inches. February is the driest month at the Billings Airport, with an average precipitation of 0.71 inches.

At Broadview, the average annual precipitation is 13.99 inches. May is the wettest month with an average precipitation of 2.65 inches. December, with an average precipitation total of 0.43 inches, is the driest month.

7.3.2 Degree-Days, Frost Penetration, and Snowfall

The normal monthly heating degree days at the Billings Airport range from 1367 in January to 9 during July. The normal yearly total heating degrees days is 7212. Nearly half the total annual degree days are accumulated during December, January, and February. The normal monthly cooling degree day total is zero during all months except June, July, August, and September. The greatest monthly average cooling degree day total is 225 in July. The normal yearly cooling degree day total is 553.

During most winters in the area, frost penetrates 8 to 20 inches into the soil. During especially severe winters, the soil may occasionally freeze to depths of 40 to 48 inches. To prevent freezing, water lines generally are buried 72 inches deep (Williams, 1987). Daily soil temperature data from the Huntley Experiment Station 20 miles east of the site indicate that monthly average soil temperatures at depths of 2 and 4 inches below the surface are below freezing only during December, January, and February. At 8 inches below the surface, monthly average soil temperatures are below freezing only during January and February. At greater depths below the surface, average soil temperatures remain above freezing throughout the winter (see Tables 7.3-4 and 7.3-5).

The normal annual snowfall at the Billings Airport is 62.0 inches. Most of the snow falls between December and April. Monthly average snowfall varies from 0.0 inches in June, July, and August to 11.6 inches in January. December through March are the snowiest months. Measurable snow normally falls on 7 to 9 days during each of these months. During November and April, measurable snow normally falls on about 5 days in each month, and it normally snows on one day in May and September.

Table 7.3-4

Average Soil Temperatures (deg F)

Huntley Experiment Station

Huntley, Montana

1961 - 1980

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2	30.2	30.8	35.9	45.6	55.9	66.9	74.0	71.4	60.0	48.0	36.0	30.2
4	29.5	30.6	35.5	45.3	55.4	66.1	73.4	70.7	60.5	49.2	37.6	31.2
8	30.8	31.4	35.1	44.3	53.4	63.6	70.7	68.8	59.6	49.7	38.8	32.8
20	33.8	33.3	35.2	42.1	50.7	58.9	65.8	65.2	59.9	52.1	42.8	36.4
40	38.8	37.1	37.3	41.5	47.4	53.9	60.2	62.1	59.6	54.4	48.0	42.1
60	42.7	40.6	39.9	42.3	46.4	51.7	58.0	61.0	60.4	56.6	46.6	46.6

Note: Soil depths are in inches. The average temperatures at the 60-inch depth are for the years 1961 through 1971.

Source: Climatological Data Montana, 1951 - 1980.

Table 7.3-5

Cumulative Frequency of Occurrence of Snow Depth (Inches)

Billings Airport, Montana

Snow Depth (in.)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	22.6	35.4	54.3	83.7	98.0	99.9	100.0	100.0	98.4	93.3	71.6	44.2
Tr	38.6	52.4	69.0	90.1	99.0	100.0			99.3	96.3	79.7	57.0
1	49.9	64.2	78.1	94.3	99.4				99.9	98.5	85.7	68.5
2	58.0	74.3	82.3	96.9	99.4				100.0	99.0	89.3	79.1
3	65.7	79.3	86.0	98.0	99.6					99.4	92.4	84.3
4	70.4	83.1	89.7	98.3	99.7					99.6	94.2	86.7
5	74.4	87.6	91.9	98.4	99.7					99.7	95.5	89.0
6	78.2	89.1	94.7	98.7	99.9					99.7	96.1	90.8
7	83.7	90.4	95.7	99.0	99.9					99.7	96.9	92.4
8	88.5	92.2	97.0	99.0	00.0					99.7	97.8	93.6
9	90.8	93.3	97.4	99.1						99.7	98.4	95.3
10	92.1	94.8	98.2	99.2						99.8	98.5	96.4
11	93.2	95.3	98.5	99.4						99.8	99.1	97.4
12	95.7	96.2	98.7	99.4						99.9	99.3	98.6
13	96.6	96.7	99.1	99.4							99.5	99.0
14	97.5	97.3	99.2	99.4							99.6	99.1
15	98.4	97.4	99.2	99.5							99.8	99.2
16	99.8	98.2	99.2	99.5							99.9	99.2
17	100.1	98.7	99.2	99.5							100.1	99.2
18	100.2	98.8	99.3	99.6								99.3
19		99.7	99.4	99.6								99.3
20		99.9	99.5	99.7								99.3
21		99.9	99.6	99.7								99.4
22		100.0	100.0	99.7								99.6
23				99.7								99.6
24				99.7								100.0
25				99.7								
26				99.7								
27				99.7								
28				99.7								
29				99.7								
30				99.7								
31				99.7								
32				99.7								
33				99.8								

Note : Total frequencies may not be exactly 100.0 percent because of rounding.

"Tr" denotes trace amount.

Source: Climatological Data Montana, 1951 - 1980.

Snow generally is light, with snowfalls greater than 6 inches are uncommon. During the 30-year period between 1951 and 1980, only 26 snowfalls of more than 6 inches were measured at the Billings Airport. During this same period, there were only 6 storms that produced one-day snowfalls of more than 10 inches. These storms occurred in March 1964 (10.5 inches), January 1975 (11.7 inches), December 1978 (13.0 inches), November 1959 (13.3 inches), January 1972 (14.0 inches), and April 1955 (15.4 inches and 23.7 inches).

Because of the frequent periods of warm weather during the winter, snow seldom accumulates to significant depths. The ground is bare for extended periods during milder winters. The average monthly snow depth at the Billings Airport is zero during May through September. During the other months, average snow depths range from a trace in September to 3.2 inches during January (see Table 7.3-6). Except for the months of December, January, and February, there normally is no snow on the ground on most days. During January, the snowiest month, the ground normally is bare about 23 percent of the time (see Table 7.3-7). During the other months, the ground is free of snow from about 53 percent of the time in March and approximately 72 percent of the time in November to 100 percent of the time during July and August.

Snow accumulations greater than 6 inches are uncommon. Snow depths of 6 inches or more normally are present only about 16 percent of the time in January and 10 percent of the time in February, with lesser frequencies of occurrence during the other months. The snow occasionally accumulates to more than 12 inches during November through April. Normally, these depths of snow occur less than 4 percent of the time in January and February and only about 1 percent of the time in November, December, March, and April.

Access to the site during winter, then, is excellent. Almost never is snow a limiting factor in the dry winters in this part of Montana. For a more detailed discussion of the excellent access characteristics of the site, refer to Section 4.1 and 4.2.

7.3.3 Prevailing Wind Direction and Speed

The prevailing wind direction at the Billings Airport is southwest during all months except May, when northeast winds prevail, and December, when the prevailing wind is from the west- southwest.

An annual wind rose for the Billings Airport is presented in Figure 7.3-2. In this figure, the percentage frequencies of occurrence of winds from each of the 16 cardinal wind directions are indicated.

The mean annual wind speed at Billings is 11.3 miles per hour. December and January are the windiest months, and July and August are the least windy. Average monthly wind speeds range from 9.6 miles per hour in July and August to 13.1 miles per hour in December.

Extremely high winds are uncommon at the Billings Airport. During the years 1965 through 1978, wind speeds greater than 25 miles per hour were observed only about 1 percent of the time (see Table 7.3-8). Wind speeds greater than 40 miles per hour are rare.

7.3.4 Regional Storm Characteristics

The regional storms which affect south-central Montana include convective summer thunderstorms, rain and snowstorms associated with Pacific and Arctic frontal passages, and orographically induced precipitation due to the passage of low pressure systems to the south. Of these, the storms most likely to seriously affect construction or operation of the SSC are the heavy winter and spring snowstorms which occasionally strike the area. These storms, which may bring 12 inches or more of new snow, are uncommon. From 1951 through 1980, only six snowstorms produced more than 10 inches of new snow.

During the years 1963 through 1977, thunderstorms occurred at the Billings Airport on an average of 26 days per year. During this same period, hail was observed on an average of 1.2 days per year. Other adverse weather conditions and their average frequencies of occurrence during this time were fog (48 days per year), freezing precipitation (6 days per year), blowing snow (6 days per year), and blowing dust (0.3 days per year).

Table 7.3-6

Cumulative Frequency of 24-Hour Snowfall (Inches)

Billings Airport, Montana

Snowfall (in.)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	56.5	59.7	57.0	69.0	94.6	99.9	100.0	100.0	96.0	88.0	70.8	63.8
Tr	73.4	75.3	76.8	85.4	97.9	100.0			98.4	94.3	85.9	79.6
1	89.5	92.0	89.5	92.1	99.1				98.7	96.7	93.8	91.8
2	96.1	95.8	94.1	94.7	99.3				99.3	97.7	96.2	95.8
3	97.5	97.9	96.6	97.6	99.4				99.5	98.4	97.4	97.2
4	98.5	99.4	98.6	98.0	99.7				99.6	99.4	98.8	98.2
5	99.3	99.8	99.2	99.1	99.8				99.9	99.4	99.1	99.2
6	99.6	100.0	99.4	99.3	99.9					99.7	99.8	99.6
7	99.8	100.1	99.5	99.7						99.8	99.9	99.9
8	99.9	100.2	99.6	99.7						99.9	99.9	99.9
9	99.9		99.7	99.8						99.9	99.9	99.9
10	99.9		99.7	99.8						00.0	99.9	99.9
11	99.9		99.8	99.8							99.9	99.9
12	99.9			99.8							99.9	99.9
13	99.9			99.8							99.9	100.0
14	100.0			99.8							100.0	
15				99.8								
16				99.9								
17				99.9								
18				99.9								
19				99.9								
20				99.9								
21				99.9								
22				99.9								
23				99.9								
24				100.0								

Note : Total frequencies may not be exactly 100.0 percent because of rounding.

"Tr" denotes trace amount.

Source: Climatological Data Montana, 1951 - 1980.

Table 7.3-7

Monthly Wind Speed Distribution

Billings Airport, Montana

1965 - 1978

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Calm	1.7	1.6	1.6	1.2	1.3	1.8	2.0	1.1	1.0	1.2	1.4	1.6	1.5
1.1- 3.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0
3.4- 5.4	6.6	6.1	7.1	5.8	6.3	7.0	7.2	6.7	6.3	6.2	7.3	6.5	6.6
5.6- 7.6	11.2	11.9	15.8	15.6	16.8	18.7	21.1	22.1	18.8	15.3	14.6	10.9	16.1
7.8- 9.8	13.9	14.8	18.2	21.6	22.3	25.1	28.7	28.9	24.2	20.0	17.1	13.6	20.7
10.1-12.1	11.9	13.2	15.5	17.3	18.0	19.1	18.4	18.8	18.5	16.8	14.8	13.5	16.3
12.3-14.3	11.4	12.2	12.6	12.1	12.6	12.3	10.2	11.1	13.0	14.1	13.8	13.5	12.4
14.5-16.6	11.3	11.7	10.7	9.9	9.6	7.3	6.5	5.8	9.0	10.9	10.0	11.3	9.5
16.8-18.8	13.0	12.0	8.5	8.0	6.6	4.6	3.5	3.1	5.2	8.2	10.3	11.5	7.9
19.0-21.0	8.4	7.8	4.9	3.6	3.3	1.9	1.2	1.2	2.2	3.9	5.5	8.2	4.3
21.3-23.3	5.7	4.9	2.7	2.1	1.8	1.2	0.6	0.6	1.2	1.8	3.1	5.4	2.6
23.5-25.5	2.0	1.3	0.9	1.0	0.6	0.5	0.2	0.2	0.3	0.6	0.8	1.9	0.9
25.7-27.7	1.5	0.8	0.6	0.6	0.2	0.2	0.1	0.1	0.1	0.4	0.7	1.2	0.5
28.0-30.0	0.9	0.8	0.6	0.4	0.2	0.3	0.2	0.1	0.2	0.3	0.4	0.5	0.4
30.2-32.2	0.2	0.4	0.2	0.3	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.1
32.4-34.4	0.2	0.2	0.1	0.2	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
34.7-36.7	0.0	0.2	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36.9-38.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39.1-41.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
>41.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Av. Speed	13.4	13.0	11.6	11.6	11.0	10.3	9.6	9.8	10.5	11.4	12.1	13.2	11.4

Note: Wind speeds are in miles per hour.

Source: Montana Wind Energy Atlas, 1987 Edition

Table 7.3-8

Average Number of Days With Occurrences of Weather Phenomona

Billings Airport, Montana

1963 - 1977

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
T	0.1	0.0	0.2	1.3	3.7	6.9	6.1	4.9	2.1	0.3	0.0	0.0
A	0.0	0.0	0.0	0.0	0.3	0.5	0.2	0.1	0.1	0.0	0.0	0.0
R	1.3	0.7	1.3	4.9	5.6	4.6	0.6	2.3	4.3	4.6	1.6	0.9
S	12.1	8.2	9.6	6.9	1.3	0.1	0.0	0.0	1.1	3.3	5.8	11.0
RW	0.6	1.7	3.6	7.1	11.5	13.1	9.1	8.8	7.7	4.1	2.1	1.3
SW	2.1	2.7	4.1	2.8	0.7	0.0	0.0	0.0	0.4	0.9	2.1	1.9
L	0.0	0.0	0.1	0.9	0.7	0.5	0.1	0.3	0.4	0.5	0.3	0.0
SG	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1
SP	0.3	0.0	0.2	0.3	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.1
IC	2.0	0.4	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.4
IP	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ZL	0.0	0.3	0.3	0.2	0.1	0.1	0.0	0.0	0.3	0.1	0.2	0.1
ZR	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.3
BS	2.5	0.7	1.5	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.7
BD	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
F	5.4	4.6	5.6	6.5	4.1	3.0	0.5	1.4	2.5	3.7	4.5	5.8
K	0.5	0.9	0.8	0.0	0.1	0.0	0.1	0.1	0.0	0.1	0.3	0.2

Key:

T	Thunderstorm	SP	Snow Pellets
A	Hail	IC	Ice Crystals
R	Rain	IP	Ice Pellets
S	Snow	ZL	Freezing Drizzle
RW	Rain Shower	ZR	Freezing Rain
SW	Snow Shower	BS	Blowing Snow
L	Drizzle	BD	Blowind Dust
SG	Snow Grains	F	Fog
		K	Smoke

Source: Original Surface Weather Observation Forms (Form MF1-10), Billings Airport 1963 - 1977.

VOLUME 8

UTILITIES

8.1 POWER

Montana offers an attractive combination of high reliability and low cost service to the SSC. The net generation capacity in Montana is 4,500 MW, of which 2,000 is hydroelectric and 2,500 is coal-fired. The largest single unit in Montana is the Colstrip Generating Station, jointly owned by Montana Power Company (MPC), Pacific Power & Light, Washington Water Power, Puget Sound Power & Light, and Portland General Electric Company. Colstrip comprises two 330 MW units and two 700 MW units for a capacity of 2,060 MW. MPC owns 50 percent of units 1 and 2 and owns or leases under a long-term arrangement 30 percent of units 3 and 4 for a total of 750 MW. In addition, MPC owns two thermal units in Billings, with a capacity of about 250 MW.

Utilities and generating plants by hydroelectric and thermal are listed in Table 8.1-1. Figure 8.1-1 shows the locations and capacities of power plants in Montana.

8.1.1 Regional Generation Capacity

The Comanche Basin is served by MPC, a healthy utility with an excellent balance of hydroelectric and coal-fired generating resources. MPC currently has a system capacity of 1,700 MW comprising 520 MW of hydroelectric and 1000 MW of thermal generation. In addition, it has 180 MW of firm power purchase agreements. In 1986, MPC served a system peak demand of 1,233 MW, 73 percent of its capacity.

MPC is part of the Western Systems Coordinating Council of the North American Electric Reliability Councils. It is intertied to transmission and generation plants owned by the federal government (through the Bonneville Power Administration), Western Area Power Administration, Idaho Power, Pacific Power & Light Company, the Rural Electrification Administration, Washington Water Power Company and Utah Power & Light Company.

These systems are interconnected by two 500 kV transmission lines and a number of 230 kV lines. The Broadview switchyard, 6 miles from the campus area, is the center for the intertie of these 500 kV and 230 kV lines. This switchyard provides optimum reliability to any facility receiving power through it.

MPC itself owns 6,838 miles of transmission lines connecting its coal-fired plants in Colstrip and Billings, and its hydro plants along the Missouri River and other rivers in Western Montana. MPC serves approximately 240,000 electric customers -- 200,000 residential, 37,000 commercial, and 2,200 industrial -- with 72 sales agreements with other utilities. Because of its low generating costs, the average annual cost of electricity for residential users was $405 for 8,566 Kwh of energy in 1986.

In 1986 MPC had a 27 percent reserve beyond peak demand. However, to prepare for future load growth, MPC has studied various capacity increase options, including hydroelectric and coal-fired plants. It has selected sites for both options. The Company will build a 240 MW combined cycle unit at its Mill Creek switchyard in Western Montana if Montana is chosen as the preferred site for the SSC. This type of unit would respond efficiently to future load demands, including the SSC, and could be built more quickly and economically than new large scale hydro or coal-fired stations.

The new Mill Creek unit will be placed at an existing major transmission hub between Butte and Anaconda. This switchyard is a major 230 kW intertie point with Bonneville Power Administration to the west and Idaho and Utah to the south. Lines from this area interconnect with the Broadview switchyard.

8.1.2 Regional Transmission Network

The Montana transmission network is shown on Figure 8.1-2 in the enclosed pocket. Other readily available maps published by the Western Systems Coordinating Council show similar information in the context of the 13-state western region. Figure 8.1-2 shows the geographical relationships of generating sources, the lines connecting them, their voltages and their owners. A diagram of the MPC grid is shown on Figure 8.1-3 in the map folder. A study of this network diagram shows that the Broadview switchyard is fed by two 500 kV transmission lines passing between the 2,060 MW Colstrip generating station and the Garrison switchyard of the Bonneville Power Administration 225 miles to the west. The Broadview switchyard also receives three 230 kV lines connecting Great Falls and Billings. Three 100 kV lines serve towns north of the Broadview area.

Several options are available among transmission lines through which power can be supplied to the SSC. The 500 kV system can provide power from the Pacific Northwest or from Colstrip. In addition, the 230 kV lines provide power from Billings, Great Falls, the new unit proposed at Mill Creek, or from stations in Wyoming, Idaho or Utah. The collider site offers an exceptionally stable and reliable power supply.

TABLE 8.1-1

Existing Electric Power Plants in Montana

Utility and Plant	No. of Units	Installed Capacity MW	Peak Capability MW	Average Annual Generation Capability MWh
Hydro Plants				
The Montana Power Company				
Mystic Lake	2	10	11	52,500
Morony	2	45	47	310,000
Ryan	6	48	60	450,000
Cochrane	2	48	50	245,000
Rainbow	8	35.6	36	292,000
Black Eagle	3	16.8	18	156,000
Holter	4	38.4	48	226,000
Hauser Lake	6	17	17	111,000
Madison	4	9	9	50,000
Thompson Falls	6	30	40	310,000
Kerr	3	168	180	1,100,000
Milltown	5	3	3	20,000
Flint Creek	2	1.1	1	8,000
Subtotal		469.9	520	3,330,500
Pacific Power & Light Co				
Big Fork	3	4.2	4.6	31,000
Washington Water Power Co				
Noxon Rapids	4	282.9	430	1,776,000
Noxon Rapids #5	1	70.7	112	0
Montana Light & Power Co				
Lake Creek	2	4.5	5.5	25,000
U.S. Bureau of Indian Affairs				
Big Creek	2	0.4	0.4	2,040
U.S. Bureau of Reclamation				
Yellowtail	4	250	288	910,000
Canyon Ferry	3	50	58	330,000
Fort Peck	5	165	205	960,000
Hungry Horse	4	285	328	843,000
U.S. Corps of Engineers				
Libby	4	420	483	1,717,000
TOTAL - HYDRO State of Montana		2002.6	2434.5	9,924,540

Utility and Plant	No. of Units	Nameplate Capacity MW	Net Peak Capability MW	Assumed Annual Energy Capability MWh
Thermal Plants				
The Montana Power Company				
J E Corette	1	172.8	180	1,070,900
F W Bird	1	69	70	459,900
Colstrip #1 and #2	2	358.4	330	2,168,100
Colstrip #3 and #4	2	466.8	420	2,759,400
Montana-Dakota Utilities Co				
Lewis and Clark	1	50	51	335,100
Glendive	1	30.7	41.4	
Miles City GT	1	23.3	28	184,000
Pacific Power & Light Co				
Libby GT	1	23.8	26	170,800
Colstrip #3 and #4	2	155.6	140	919,800
Washington Water Power Co				
Colstrip #3 and #4	2	233.4	210	1,379,700
Montana Light and Power Co				
Troy	1	3	3.2	21,000
Libby	3	13.3	14.5	95,200
Puget Sound Power & Light Co				
Colstrip #1 and #2	2	358.4	330	2,168,100
Colstrip #3 and #4	2	389.0	350	2,299,500
Portland General Electric Co				
Colstrip #3 and #4	2	155.6	140	919,800
TOTAL - THERMAL State of Montana		2503.1	2334.1	14,951,300

Power easily can be provided to the site with the addition of short 230 kV lines from the Broadview switchyard to power distribution substations at the east and west clusters. These two lines will be synchronized 230 kV lines from the 230 kV portion of the switchyard; thus, accomodating the requirement for a "make before break" capability. The proposed 230 kV facilities will be designed with a redundant "breaker and one half" arrangement that provides for continuous service to the SSC should a single line failure occur.

On Figure 8.1-4, a "breaker-and-one-half" system is tied to the three incoming 230 kV lines from Billings and Great Falls. Figure 8.1-5 shows the two new feeder lines to the cluster areas.

8.1.3 Stability and Reliability of the Network

The Broadview switchyard interconnects seven transmission lines with voltages of 230 kV or higher, any one of which has the capacity to provide full load service to the SSC. The primary purpose of the station is to provide a connection from the 500 kV Colstrip transmission lines to the Billings area to serve loads of MPC. This switchyard provides an added benefit in increasing substantially the stability of the Colstrip generating complex by reducing the impedance change resulting from the loss of a line for any reason.

The service at the Broadview switchyard is as reliable or better than that of any major transmission bus in the Rocky Mountain states. The basic bus design is the so-called "breaker-and-one-half" scheme for both the 500 kV and the 230 kV buses. With two 600 MVA auto-transformers between the 500 kV and 230 kV buses, there is adequate transformer capacity to meet electrical load requirements of the SSC. The logical method to connect the SSC would use two synchronized 230 kV lines originating from the Broadview switchyard, one to each of the east-cluster and west cluster switchyards. The existing switchyard design allows for additional lines to be added. Two lines would require three 230 kV circuit breakers to follow consistently the "breaker-and-one-half" scheme shown in Figure 8.1-4.

The high reliability of the Broadview 230 kV bus was demonstrated during a major breakup of the western system that occurred February 12, 1985. In this event, power to tens of thousands of customers was interrupted. In Montana, 374 MW of customer load was shed. However, the Broadview switchyard still had retained power through the system failure.

MPC has a design to control transmission system stability whose primary objective is to retain the interconnection between Montana and the Northwest for any credible contingency. Systems are in place to perform this task while preventing the voltage at any load bus from dipping below 80 percent of the pre-event voltage level except during faults. Thus, there is a high probability that in the aftermath of any event, the Broadview bus will be connected by at least one 500 kV line to the Pacific Northwest. Thus, the large hydroelectric capacity of stations such as Coulee Dam will be available to meet emergency reserve requirements. If this path were severed, the two lines to the east are connected directly to the Colstrip station, which would have surplus capacity under those circumstances.

The other three lines connected at Broadview are 230 kV lines. One connects Broadview to 210 MW of hydropower in Great Falls plus other generating plants belonging to MPC and the U.S. Bureau of Reclamation (USBR). These units have a combined capacity of 317 MW. The other two 230 kV lines connect the Broadview station to the greater Billings area. One of these ties directly to the coal-fired Corette unit rated at 180 MW, and the 70MW Bird unit. Billings is the interconnection point to the Pacific Power and Light system in Wyoming and to USBR's. There is a 288 MW Yellowtail hydroelectric plant approximately 41 miles south of Billings. The second 230 kV line into the greater Billings area also connects to major transmission lines to the west, including Mill Creek.

About half the generating capacity in Montana is hydroelectric, which inherently provides for a more rapid recovery in the unlikely event of a system blackout.

The stability of the transmission system is inextricably linked to the stability of the Colstrip generating facility. With all four units on line, Montana is a net exporter of power. In fact, the net capacity of the station is roughly 1.5 times as great as the 1986 peak generation of MPC. There are, of course, other entities with load responsibility in Montana, but with full generation at Colstrip, the area could easily be exporting as much as 1500 MW.

A system disturbance in Montana would most likely cause Colstrip to accelerate and then either pull out of step or oscillate as it regains synchronism at a more advanced relative phase angle. The system is designed to maintain these units in step. In situations where this is impossible, such as the simultaneous loss of both 500 kV lines, MPC has automatic controlled unit dropping at Colstrip to preserve as much of the generation as possible while preventing voltage swings below 80 percent of the steady-state bus voltage on any load bus.

This unit-dropping scheme protects all loads in Montana from extreme voltage swings lasting longer than the normal fault clearing times. It also provides stable performance that is far superior to that of any other utility's. No other utility is known to have such a device.

8.1.4 Utility Rate Schedules

MPC proposes to negotiate a long-term power sales agreement for the power requirements of the SSC. Based on the addition of a 240 MW combined-cycle unit and a combination of utility ownership and other financing arrangements, the estimated cost of energy delivered to the SSC site is 34 mills/kWh in 1987 dollars. Actual demand and energy charges will be determined at the time the power contract is executed. It should be noted that fuel and other cost increases in the period to 1996 could affect the cited power costs.

The cost of energy is competitive and should be among the lowest of states submitting proposals for the SSC. A comparison of representative power costs for selected cities, based on published 1985 data, shown on Figure 8.1-6, demonstrates that there will be significantly lower power operating costs for the Montana site.

8.1.5 Future Power Demand and Cost Projection

The current projection for future power demand is given in Table 8.1-2. The expected load growth without the SSC is about 1.8 percent per year over the next 9 years; the projection increases by approximately 17 MW average per year when the impact of the SSC is taken into account. This 17 MW/year increase is the result of increased population and employment, and does not include the power requirements of the SSC facility itself.

The assumptions in calculating the increased demand are:

- 4500 maximum construction employees
- 2500 permanent employees
- 240 MW plant constructed to supply electrical needs of the SSC (at the costs shown in Section 8.1.4).
- Estimated population increase of 10,000 within the MPC service area.

These impacts and the addition of the plant at Mill Creek may result in a rate increase (spread over all classes of customers) of approximately 2 percent. It will be noted that Colstrip Unit 4 is not shown in Table 8.1-2. This unit is being operated but is not rate-based by the Montana Public Utilities Commission. Power taken from the unit is considered "purchased" power. The current output of the plant is used for power sales to other utilities.

8.2 INDUSTRIAL COOLING WATER

The proposed source of industrial cooling water is a new 18-inch pipeline from the Billings city water service to the southeast perimeter of the collider property. The pipeline will deliver 2,600 gpm of potable water. The pipeline and pumping stations will be constructed and paid for by a Rural Special Improvement District.

8.2.1 Available Water Sources

Three water sources were investigated:

- groundwater
- Yellowstone River water
- Billings city water

Groundwater is available in the Comanche Basin in several formations for several hundreds of feet deep. In addition, the Madison formation is found between 6,000 and 8,000 feet deep. The upper aquifers are suitable for domestic use and to supply water for stock ponds. At flows of only 15 gpm, these aquifers are not suitable to supply the SSC except as isolated water sources. The town of Broadview receives well water from an aquifer slightly deeper than local farm wells and obtains a yield of only 80 gpm.

Geological investigations concluded groundwater would not be a concern in tunnel construction because of the low permeability of the upper formations and because water in the basin comes only from the recharge of approximately 13 inches of annual precipitation.

One land owner reported that when an exploratory gas well drilled on his property (Campus expansion area C) a number of years ago encountered water in the Madison formation, the force caused the well casing nearly to come out of the ground. This well was not developed because of the cost and because there was no need for large quantities of water. While there is a significant quantity of water available in the Madison formation, probably more than enough to supply the SSC requirements, the water is believed to be non-potable (Bergantino, et al., 1985). This option could not be offered to DOE without further exploratory drilling.

Water can be provided through a new pipeline to the site either from the existing Billings water supply or from a new intake from the Yellowstone River. A new, independent source from the river will require acquisition of water rights, construction of an intake and additional permitting. Since the site is no closer to the river than to the Billings supply, it is far more reasonable to use the existing Billings supply as the preferred option. The pipeline can be constructed early enough in the design phase of the project to be available by the start of construction.

Based on these considerations, water supplied by the city of Billings through a new pipeline is the option selected for the SSC. The city has more than adequate treatment and supply capacity, and the quality of the water will be excellent. Further demineralization for boiler quality water may be necessary at the site; however, additional treatment should be minimal because the water already is potable.

The water supply system from Billings to the site will be provided through a Rural Special Improvement District. The resolution by the city of Billings authorizing the special district is included in Appendix 4B.

8.2.2 Estimated Cost of Delivered Water

The estimated cost for delivering water to the collider ring boundary near access point E2 will be $1,263 per million gallons. Further distribution of the water system beyond the terminating point will be at DOE expense. From a distribution system around the ring the estimated cost would be $2,000 per million gallons. This cost is based on the current Billings heavy industrial rate of $491.03 per million gals plus the estimated cost of $771.97 for the construction of 16 miles of new pipe line, based on 3 percent financing, 25 year amortization and 1,500 gpm average consumption. The cost also includes operation and maintenance and other indirects associated with the pipe line extension. A planned routing of the water line is shown on Figure 8.1-5. The routing of the water line to the campus area follows the planned main access road shown on Figure 3.1-3 in the map folder. This is the hypothetical shortest distance route to the campus from the termination point to which the Special Rural Improvement District would supply a pipe line.

8.2.3 Water Properties

The most recent analysis of Billings city water was done by the State of Montana in August 1986. The water is in compliance with the National Interim Primary Drinking Water Regulations, as set by the Safe Drinking Water Act. This analysis is summarized in Table 8.2-1 below:

Table 8.2-1

Analysis of Billings City Water

Constituent	mg/l
Calcium (Ca)	28.0
Magnesium (Mg)	9.8
Sodium (Na)	18.4
Potassium (K)	-
Bicarbonate (HCO_3)	97.6
Carbonate (CO_3)	0.0
Chloride (Cl)	-
Sulfate (SO_4)	54
Fluoride (F)	0.38
Phosphate (PO_4 as P)	-
$NO_3 + NO_2$ (Total as N)	0.04

For a detailed analysis of Billings city water based on samples taken August 1986, refer to two items in the Appendix:

- Water Treatment Plant Process Report - 1985-1986 (pp. 22-23)

This is a summary of the data collected for water discharged from the treatment plant from July 1985 through June 1986.

- Department of Health and Environmental Sciences Report, December 3, 1986

This report summarizes the chemical analysis of Billing's drinking water by the state laboratory in Helena. The data in Table 8.2-1 is from this report.

8.2.4 Evaporative Cooling

The cool, dry climate of Montana lends itself well to effective evaporative cooling, which is likely to be used for heat rejection. Evaporative cooling is related to the wet bulb temperature, specified by the Conceptual Design Report as 78°F. A comparable design temperature at the Montana site would be approximately 66°F. Assuming 85°F water, 30°F temperature rise of the water, and 100 MW of thermal duty, the cooling towers at the Montana site would be 40 percent smaller, with costs proportionately less than for the 78°F design condition. Other advantages would be reduced annual costs of pumping power, fan power, and maintenance.

8.5 WASTE AND SEWAGE DISPOSAL

8.5.1 Available Sewage Treatment Facilities

There are no adequate sewage treatment facilities near the campus. A "greenfield" treatment plant will probably have to be constructed to serve the SSC. Effluent from the sewage treatment plant will be combined with cooling tower blowdown water and ponded for evaporation. The estimated area of the pond for the total site is 280 acres and could be located at any of several sites near the campus for optimum operation and cost.

8.5.2 Solid Waste Disposal Resources

The City of Billings operates a solid waste dump 2 miles south of the city. This dump currently has adequate capacity to serve the city and the SSC facility through the year 2010. Contractor-operated waste disposal trucks will haul material to the dump.

Hazardous waste can be transported to the licensed treatment facilities in Denver or Salt Lake City by licensed carriers such as Special Resource Management, Inc. (SRM), a subsidiary of MPC. SRM, with offices in Billings, operates a five-state fleet of fully licensed hazardous waste vehicles with highly trained and experienced drivers.